

# BIOLOGY



HIGHER SECONDARY
FIRST YEAR

VOL. I



TAMILNADU TEXTBOOK SOCIETY

# BIOLOGY

## VOL. I

**Higher Secondary—First Year**

UNTOUCHABILITY IS A SIN
UNTOUCHABILITY IS A CRIME
UNTOUCHABILITY IS INHUMAN

**TAMILNADU TEXTBOOK SOCIETY**
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## Chapter I

# AN INTRODUCTION TO THE SCIENCE OF LIFE

The immense variety of architecture which has been utilized in the structural designs of animals is one of the greatest fascinations to the professional Zoologist as well as to an ordinary man. Equally exciting are the chemical inter-actions by which the animals have solved their functional problems. Our knowledge in these respects have expanded greatly in recent times due to modern scientific methods employed in the study of Biology.

**The fields of Biology:** A great many sciences are included under the term Biology. It is generally recognised that two great groups of living things exist - viz. Plants and Animals. The study of plants is called Botany (Gr. botane, plant) and the study of animals is called Zoology (Gr. Zoon, animal + logos, discourse). Within these divisions there are sub-divisions of biology relating to the study of particular groups of animals and plants e.g. Ornithology (study of birds), Bacteriology (study of bacteria) etc.

From entirely different points of view, the fields of Biology may be classified into Morphology, concerned with structure, Physiology (Gr. Phuris, function) having to do with function; Anatomy (Gr. anatomia, to cut up) which is the study of structure as determined by dissection; Histology (Gr. histos, tissue), the study of tissues (microscopic anatomy); Taxonomy (Gr. taxon, arrangement), the study of classification of living organisms and Palaeontology (Gr. Palaios, ancient) the study of fossil organisms. Certain fields are both morphological and physiological. They are, Cytology (Gr. cytos, cell), the study of cells; Embryology, the study of development; Genetics (Gr. genesis, to be born), the study of heredity; and Ecology (Gr. oikos, house), the study of the relations of organisms to each other and their environments.

Though these branches of study are varied and specialised there are certain fundamental principles which unify the several fields of Biology.

**Need to study Biology:**

Biology is a complex science with a number of problems yet to be solved. This alone is a sufficient challenge to an enquiring and intelligent mind. Further (1) man is the product of the biological heritage of the past and he is a product of the evolutionary process. Since there is an underlying unity of structure and function throughout the animal kingdom, much information can be obtained by studying other animals (2) Biology is of practical importance because of our dependence upon animals for many products such as food, clothing, drugs, etc. (3) A study of Biology is necessary for pre-professional work in medicine, agriculture, dentistry, veterinary, sanitary engineering,. conservation etc. (4) It forms a basis for psychological and sociological studies. (5) Animals influence man's welfare in harmful ways and a knowledge of their habits enable us to eradicate them.

Regardless of these values, the field of Biology can lead the student to appreciate all beauty, whether in nature or in art, and to respect others as himself, which, according to Thomas Huxley, defines an educated man.

**This is Life: The characteristics of living matter:**

In addition to the approaches to the study of Biology already mentioned, there are other approaches of study, viz. (1) a descriptive approach, based largely on observations and (2) an experimental approach. This latter approach has become greatly advanced in the past 75 years. Investigations in the biological sciences are not easy, however, for the biological units show a great variety. Two healthy individuals of the same age, size and environment may react very differently to some experimental factor. For instance, a drug may be highly effective in one individual; in another it may react in an entirely different manner. It is one of the reasons why biological investigation has not yet solved some diseases such as cancer.

When the experimental method gained a foothold, workers in biology were alert to new techniques whenever they saw them. Thus, X-rays and tracer techniques were put to use in Biology experiments. Much importance was also given to Mathematics to express the life process. Many concepts and principles of

Physics and Chemistry were used in the experimental pursuits of Biology.

**Protoplasm as material basis of Life:**

Any living thing, plant or animal, regardless of its size or complexity of organization may be called an organism. Living matter was first called **protoplasm** by Purkinje (Gr. protos, first-plasm, anything formed) in 1840 and **sarcode** by Dujardin in 1835. *It is often stated that organisms are composed of protoplasm* but it must be emphasised that it occurs only as organized individuals and it cannot be considered apart from the organism. It was first thought that protoplasm was a definite chemical substance; but investigation has shown that it is not a single chemical substance but is made up of different compounds and that it differs in every species of plant and animal life and probably in every kind of cell. Owing to the uniformity of the life processes within all animals and plants, we speak of the properties of protoplasm as though it were one single kind of substance. Fortunately, many of the modern techniques enable us to study the organism or parts of an organism while vital activities are proceeding. The application of these techniques has led us to organize our information concerning the properties of protoplasm into three categories: the biological, the physical and the chemical. All the three categories are inter-related.

**A. Biological properties:**

Living matter exhibits the phenomena of growth, reproduction, movement and irritability. It has become increasingly evident in recent years that no sharp line of demarcation can be drawn between living and nonliving systems. The implications of this statement can be understood better if the above four features are considered in detail.

1. *Growth and metabolism:*

Growth is the most complex of all vital processes. By growth, organisms increase in volume by forming new protoplasm and what is more, the new protoplasm is synthesized from simple chemical compounds. Further, the protoplasm is peculiar to the organism which synthesizes it and is the structural basis of the organism, providing energy for all activities. Metabolism

is the term used to include these complex chemical changes. These processes which use energy to build up compounds are said to be anabolic; those by which substances are broken down thereby releasing energy, are termed catabolic.

Animals are unable to make organic compounds from simple inorganic substances. In this respect they differ from plants, which manufacture sugar (glucose) from carbon dioxide ($CO_2$) from the air, water ($H_2O$) from the soil and energy from sunlight. Chlorophyll in the plants is also necessary. The reaction for the formation of glucose from carbon dioxide and water is better understood and can be illustrated by the following simple equation:

$$6\ CO_2 + 6\ H_2O + \text{energy} + \text{catalyst} = C_6\ H_{12}\ O_6 + 6O_2$$

This reaction is aptly named photosynthesis and is one of the most important manufacturing processes on earth, because energy from the sun is 'stored' in glucose for later use by the organisms. Glucose once formed, forms the keystone for the formation of other complex compounds such as carbohydrates and fats or lipids; and by the addition of nitrogen, the amino acids and proteins.

Since animals must have organic food, plant products are necessary either directly or in the form of protoplasm built up by other animals out of plant food. Before animal growth is possible, food must be converted into living substance. This is done by digestion and assimilation, which is an important anabolic process. Energy that is contained in the organic molecules in protoplasm and in stored substances in the body is liberated when these molecules are broken down in oxidation. A single example of the oxidative process is as follows:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Oxidation, therefore is a breaking down of protoplasm and is a catabolic process.

It is thus evident that protoplasm is a remarkable chemical laboratory. Some insight has been gained with regard to the way in which the protoplasm performs its chemistry. The key lies in the presence of special proteins, the enzymes which control the rate of the chemical reactions and act as the organic catalysts. To understand life processes fully, our knowledge of the enzymes and what they do within the protoplasm must be explored.

Equally important in growth is the increase in the amount of water and salts. In other words, as the amounts of carbohydrates, lipids and proteins are increased, the amount of water must also increase, or the protoplasm would become progressively more concentrated.

2. *Reproduction:*

If the plants and animals are to be successful they must not only form new protoplasm but must also create new individuals. It is therefore imperative that organisms reproduce if they are to survive.

There are two processes involved in reproduction.

(*a*) Replacement of worn out or damaged parts - regeneration.

(*b*) Creation of new individuals.

These two processes and the mechanisms by which they are brought about are among the most fascinating problems of modern biology.

3. *Movement:*

Movement is one of the most vivid characteristic of living matter. Protoplasm is never stationary and there is corresponding expenditure of energy. A seed or a hibernating animal may appear to be without visible movement but careful examination will show that there is slow movement of the protoplasm, slight movement of the blood etc.

4. *Irritability:*

Awareness of its surroundings and ability to make responses to a variety of stimuli are fundamental characteristics of living systems. It involves the ability to distinguish to some extent between the stimuli which reach the protoplasm, and often is associated with special receptors. Mere awareness is not sufficient; the organism must respond. Responses may be positive or negative; and the response may occur immediately or be delayed for a longer period. Continued stimuli may result in the organism producing structural adaptations.

**B. Chemical Properties:**

The chemical elements found in living matter are not unique to the protoplasm. It is the relative proportion of the compounds

in protoplasm that is significant. Nearly 95% of the protoplasm is formed of six elements, viz. oxygen, hydrogen, carbon, nitrogen, calcium and phosphorous and the remaining elements constitute the 5%. Of these six elements, carbon is specially important, because of two special properties. It has four valence bonds, which allow it to attach at four places with the atoms of other elements and secondly, the carbon atoms have the property of combining with themselves.

**C. Physical Properties:**

It is not possible to separate completely the properties of protoplasm into physical and chemical properties but has been done so here only for convenience and better understanding.

Protoplasm has a higher water content and is therefore a fluid. It varies however in its consistency. It becomes very gelatinous at times (gel) and can change very rapidly to watery condition (sol). This characteristic has advantages, in that the protoplasm can utilize the advantages which accompany the fluid movement and also can retain the stability of the gel or semisolid state.

Many minute granules can be seen in the protoplasm with the aid of the microscope. When the protoplasm is in a liquid state or in the sol state, the granules can be seen moving about. This is known as the Brownian movement, having been discovered by an English Botanist, Robert Brown in 1827. This type of movement is also seen in water and other liquids and is not necessarily a sign of life.

Protoplasm is a *colloid*; a physical condition in which relatively large particles, such as clumps of molecules and very large molecules are suspended in fluid. The particles in the protoplasm have a great affinity for water and chemical reactions occur on their surface. Since the number of surfaces presented by the colloidal particles are exceedingly numerous, and since the surface area presented by the particles are enormous, countless number of chemical reactions can go on simultaneously in the protoplasm.

Other important features of the physical phase of the protoplasm are the direct results of the high water content. Water is an almost universal solvent and many diverse chemical substances dissolve in water and thus can be incorporated into the protoplasm. Insoluble substances like oils, form *emulsions* with water in the

protoplasm. Secondly, water has a high specific heat which means that it changes temperature slowly. This factor provides a safety factor to the organism when their surroundings become suddenly hotter or cooler. Thirdly, water changes its physical state within a very narrow temperature range. At 0°C (32°F) water is a *solid*, ice; between 0°C and 100°C (212°F) it is a *liquid;* above 100°C water becomes a *vapour*, steam. These facts limit the protoplasm's existence; it can survive freezing under special conditions for a very short time but is coagulated and destroyed at high temperature. Organisms are less adaptable to higher than to lower temperatures, probably because the enzymes are destroyed quickly by heating and the membranes become more permeable.

**Living and non-living matter:**

The above characteristics were once thought to be peculiar to protoplasm. Modern techniques show that many models can duplicate them. In fact, such problems like permeability of the membrane, transmission of impulses along nerve fibres, nature of movement of materials into and out of the protoplasm, etc., have been studied through models.

The study of *viruses* have also demonstrated that there can be no absolute distinction between living and non-living matter. They undoubtedly provide a connecting link between ordinary molecules and protoplasm. Viruses can therefore solve many biological problems and are extremely helpful in their analysis in experimentation.

## Chapter II

# BIOLOGY

*Biology* is the study of all living organisms. The living organisms are of so many millions of types that it is impossible for any one to study all the different types. To help one, to have a fair knowledge of the ways of life, of the living organisms, classification of the organisms based on similarities and differences has been devised.

Living organisms include both plants and animals. These two can be distinguished by looking at the different characteristic ways of the organisms. Points that help us differentiate plants and animals are (1) method of nutrition (2) nature of growth (3) form and symmetry (4) locomotion and (5) details of the cell structure. However, we should not lose sight of the fact that there are regions where this clear difference is not possible. The study of the plants constitutes *Botany* and the study of animals becomes *Zoology*. There are many branches of both the disciplines.

Animals live in different habitats. They are of different sizes ranging from a microscopic level to huge forms like the whale. The animals have been classified into various levels of organisation in structure, form, and ways of life. The study of classification is known as *Taxonomy*.

The living world is divided into two kingdoms namely (1) the *plant kingdom* and (2) the *animal kingdom* or *kingdom Animalia*. The animal kingdom is broadly divided into sub-kingdoms namely (1) *Sub-kingdom Invertebrata* comprising of animals without backbone and (2) *Sub-kingdom Chordata*. This division is based mainly on the fact that Invertebrate animals do not have a dorsal median supporting rod or notochord as it is called, while the chordates have them. Besides this, there are other points of differences also. The chordates have paired pharyngeal gill clefts, a post anal tail, a ventral heart, a hepatic portal system, and a dorsal tubular central nervous system. Besides, no chordate has more than two pairs of limbs. The respiratory pigment is in the blood corpuscles. The

common Cockroach is an example of the Invertebrata and the Frog, and we too, are examples of chordata.

Each sub-kingdom is further divided into many big groups called *phyla*, based on radically different plans of organisation. A phylum is a big group having in it, all animals, with the same basic plan of organisation of their bodies.

Each phylum, is split up, for convenience into different *classes*, on the basis of very significant variations, in the plan of organisation. The classes are further broken up into *orders*, on the basis of clearly observable differences. Each order consists of many *families*, and each family is made of several *genera*. Every genus may have, many different *species*. The species forms, the ultimate level or basic level. The species is defined as a group of animals which will normally interbreed in a natural population and which maintain the same chromosomal set up.

Thus we find a gradation in classification

- Kingdom
  - Sub-kingdom
    - Phylum
      - Class
        - Order
          - Family
            - Genus
              - Species

Every animal can be fitted in this scheme of gradation. For example, the brown cockroach, is called scientifically, as *Periplaneta americana*. The first half of the name, Periplaneta is the name of the genus, *americana* is the name of the species. All organisms, even plants, are named like this, by two names, one a generic name and the other, a specific name. Usually the generic name is written with a capital letter, and the specific name with a small letter. The same genus, may have another species such as *Periplaneta orientalis*, the yellow and black cockroach.

As our knowledge expands, further divisions of these grades, like sub-phylum, sub-class, sub-order, sub-family etc. are introduced.

This method of naming every organism by two names is called *Binomial nomenclature*.

This was first invented by Carl Linnaeus (1707–1778) a Swedish naturalist.

How the cockroach fits in the scheme of classification is shown below.

| | | |
|---|---|---|
| Kingdom | — | Animalia |
| Sub-kingdom | — | Invertebrata |
| Phylum | — | Arthropoda |
| Class | — | Insecta |
| Order | — | Orthoptera |
| Family | — | Blattidae |
| Genus | — | *Periplaneta* |
| Species | — | *americana* |

Similarly the green pond frog is placed in classification as below:

| | | |
|---|---|---|
| Kingdom | — | Animalia |
| Sub-kingdom | — | Chordata |
| Phylum | — | Chordata |
| Sub-phylum | — | Craniata or Vertebrata |
| Class | — | Amphibia |
| Order | — | Anura |
| Family | — | Ranidae |
| Genus | — | *Rana* |
| Species | — | *hexadactyla* |

The important phyla of the animal kingdom are given below:

1. Phylum — Protozoa (e.g.) Amoeba, Euglena, Paramoecium Plasmodium. etc.
2. Phylum — Porifera (e.g.) Sponges.
3. Phylum Cnidaria or (Coelenterata) (e.g.) Hydra, Jelly-fishes
4. Phylum — Platyhelminthes (Flat worms) (e.g.) Planarians, Tapeworm, Liver fluke.
5. Phylum — Aschelminthes (Nemathelminthes) (Round worms) (e.g.) Ascaris.
6. Phylum — Annelida (e.g.) Earthworm, Nereis, Leech.
7. Phylum Arthropoda (e.g.) Crab, Prawn, Centipede, Millipede, Insects, Scorpion, Spider.
8. Phylum—Mollusca (e.g.) Clams, Snails, Slugs, Octopus

9. Phylum — Echinodermata (e.g.) Star fishes.

10. Phylum Chordata is divided into 2 groups namely Acrania or Prochordates and Craniata

    Prochordates — (e.g.) Amphioxus

    Vertebrates
    Craniata — (e.g.) Shark, Bony fishes, Frog, Snakes, Turtles, Lizards, Crocodiles, Birds, Mammals.

**Phylum Protozoa:** The animals belonging to this phylum have the following general characters:

1. The animals are very small and microscopic.
2. The animals are made of single cells. So these are called unicellular organisms.
3. There is no symmetry.
4. Various activities of life are carried on by parts of the cell called organelles.
5. The animals reproduce by fission and in some cases by conjugation and by sexual methods.
6. There is no natural death as the mother's body is divided among the offspring.

This phylum is divided into five classes namely—

(1) Rhizopoda or Sarcodina, (2) Mastigophora or Flagellata, (3) Ciliata or Ciliophora, (4) Sporozoa and (5) Suctoria.

*Class* (1) *Rhizopoda* (e.g.) Amoeba:

**Animals have blunt temporary projections called pseudopodia. There is no definite shape of the body. Locomotion is by the pseudopodia.**

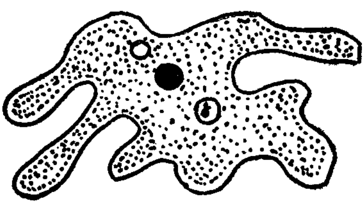


**Fig. 1. Amoeba**

*Class* (2) *Mastigophora* (e.g.) Euglena:

Animals have a definite shape. The locomotor organ is the long whip like flagellum or mastix. Many forms have chloroplasts.

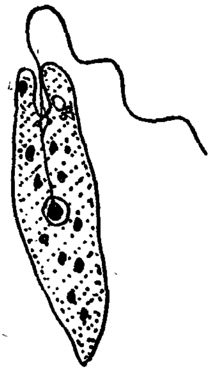


Fig. 2. Euglena

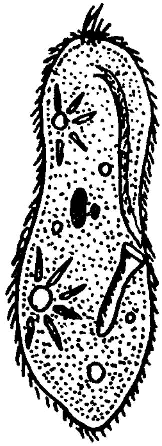


Fig. 3. Paramoecium

*Class* (3) *Ciliata* (e.g.) Paramoecium:

Animals are provided with vibratile hair like cilia which help locomotion. Some have two nuclei. A method of reproduction called conjugation is common.

*Class* (4) *Sporozoa* (e.g.) Plasmodium:

Many of these are parasites requiring another host to live upon. No special locomotor organs are present. Reproduction is both by asexual and sexual methods. Some require two hosts to complete the life history.

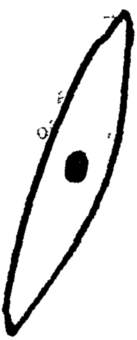


Fig. 4. Plasmodium

*Class* (5) *Suctoria* (e.g.) Acineta:

Animals are sedantary. They have tentacle like suckers with the help of which they feed.

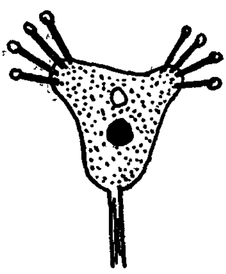


Fig. 5. Acineta

**Phylum Porifera:** The animals in this phylum are characterised by—

1. Except a few, all animals are marine, and sedantary.
2. Animals are multicellular, but there is no true tissue formation.
3. Animals have a detailed canal system through which sea-water is made to flow.
4. Special collared cells with flagella called Choanocytes are seen on the inner walls.
5. Body is reinforced by Calcareous spicules of different patterns.
6. No part of the body is dependent on other parts and so power of regeneration is great.
7. Both sexual and asexual reproduction are present.

This phylum is divided into 3 classes namely (1) **Calcarea,** (e.g.) Leucosolenia (2) Hexactinellida (e.g.) Hyalonema and (3) Demospongiae (e.g.) Spongilla

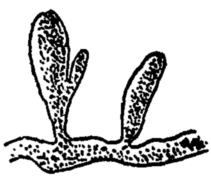


Fig. 6.
Leucosolenia



Fig. 7.
Hyalonema



Fig. 8.
Spongilla

**Phylum Cnidaria** (Coelenterata): This phylum consists of animals with the following general characters:

1. All are multicellular animals showing a tissue grade of organisation.
2. Almost all are marine animals except the Hydra.
3. Animals exhibit radial symmetry.

4. Body wall is made of two layers of cells namely the ectoderm and the endoderm with a jelly like mesoglea in between. So the animals are said to be *diploblastic.*
5. There is a *coelenteron* or gastrovascular cavity which is both the body cavity or coelom and the alimentary cavity or enteron.
6. Stinging cells or Nematocysts are peculiar to this phylum. These help in feeding and in defence.
7. Some animals secrete a horny or calcareous skeleton which becomes the coral.
8. There is a loose network of nerve cells.
9. Some forms show polymorphism with division of labour among the branches.
10. The life history shows the phenomenon of alternation of generations.

This phylum is divided into 3 classes namely (1) Hydrozoa, (2) Scyphozoa and (3) Anthozoa.

*Class* (1) *Hydrozoa* (e.g.) Hydra:

This is a fresh water coelenteratae. Body is cylindrical. The base is attached to the substratum. The free end has the mouth, surrounded by a set of hollow tentacles. The body wall is made of two layers, an outer ectoderm and an inner endoderm. In between the two, there is a jelly called mesoglea. The tentacles are rich in special stinging cells called Nematocysts. There is only one cavity inside the animal, called coelenteron or gastrovascular cavity. The animal moves from place to place, by gliding, somersaulting or caterpillar like movements. It feeds on water fleas. The digestion is partly extracellular and partly intracellular. There is no anus. There is a network of nerve cells throughout the body. The animal reproduces asexually by budding and also sexually by forming gametes.

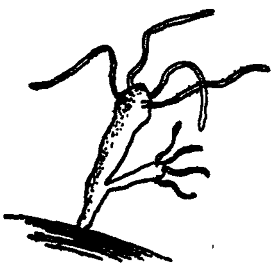


Fig. 9. Hydra

*Class* (2) *Scyphozoa* (e.g.) Aurelia:

This is popularly called the jelly-fish. This has an umbrella like part from which root like oral arms hang down. This marine form is the medusa stage. The polyp stage is shortlived. Stinging cells are in the oral arms. There is a well defined canal system in the medusa.

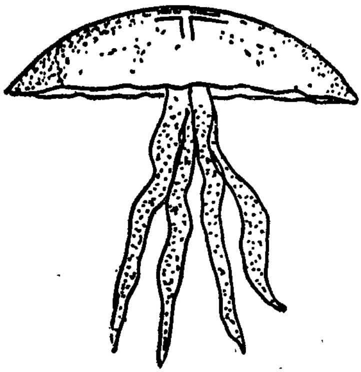


Fig. 10. Aurelia

*Class* (3) *Anthozoa* (e.g.) Sea-anemones.

These sedantary marine animals look like flowers. The body is cylindrical with a flat top in the centre of which is the mouth. Surrounding the mouth, there are numerous finger like tentacles. The cavity inside is separated into many chambers by mesenteries. Many anemones secrete a calcareous skeleton, which becomes the coral.

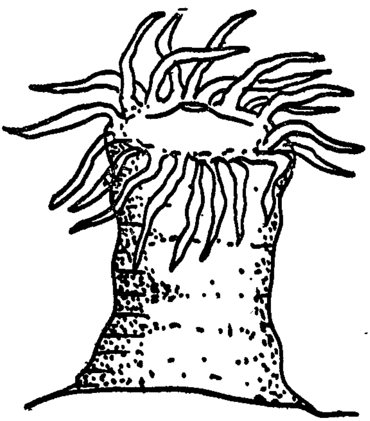


Fig. 11. Sea-anemone

**Phylum Platyhelminthes** (Flat worms); The animals in this phylum are having the following general features:

1. The animals are dorso-ventrally flattened.
2. They show bilateral symmetry.
3. Animals have 3 main layers of cells namely ectoderm, endoderm and mesoderm. So these are said to be triploblastic animals.
4. Animals reach an organ system level of organisation.

5. There is no coelom, as it is occupied by parenchyma cells.
6. Excretion is effected by peculiar cells called flame cells or solenocytes.
7. A primitive brain with 2 lateral nerve cords is seen.
8. Reproduction is by sexual method. Most of the animals are hermaphrodites.
9. Adaptation to parasitic existence is well developed in many forms.
10. Power of regeneration is marked.

This phylum is divided into 3 main classes namely (1) Turbellaria, (2) Trematoda and (3) Cestoda.

*Class* (1). *Turbellaria* (e.g.) Planarians:

These are small flat worms, usually **free living.** Eyes are present. There is a definite antero posterior axis. Animal shows extraordinary regenerative powers.

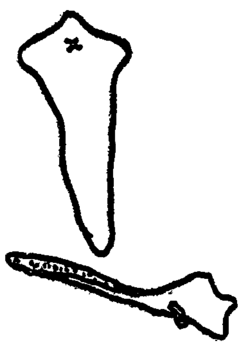


Fig. 12. Planarian

*Class* (2). *Trematoda* (e.g.) Liver fluke:

This is a parasite, in the liver of sheep. Animals show extreme adaptation to parasitism. Loss of locomotor organs, sense organs and digestive glands, development of powerful attachment organs

like suckers, and extraordinary reproductive systems, to produce a large number of young ones are some examples of this adaptation. This animal completes its life history in two hosts namely sheep and a pond snail. Paedogenesis (i.e.) larval multiplication is characteristic.

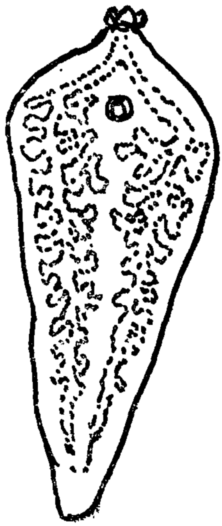


Fig. 13. Liver-fluke

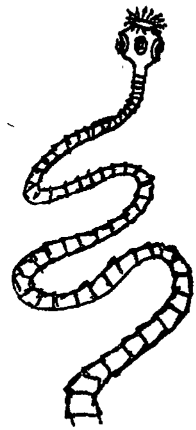


Fig. 14. Tapeworm

*Class* (3). *Cestoda* (e.g.) Tapeworm:

This is an intestinal parasite in man. It has a head like scolex with hooks and suckers for strong attachment. The body looks like a flat tape with numerous segments called proglottids. The body is covered by an enzyme resisting cuticle. Locomotor organs, sense organs, and digestive organs are absent. Every segment has a complete male and female reproductive system. Excretion is by flame cells. Life history is completed in two hosts namely man and pig.

**Phylum Aschelminthes or Nemathelminthes (Round-worms)**

The animals in this phylum have the following general characters:

1. Animals are long, cylindrical and without any segmentation.

2. Animals show sexual dimorphism. The females are, usually straight and the males are shorter and posteriorly curved.
3. The body wall has a cuticle and a syncytial epidermis.
4. A true coelom is absent, and hence it is called pseudo-coelom.
5. Sexes are separate. A large number of eggs are produced.
6. Some are free living and many are parasitic.

This phylum is having only one class by name Nematoda. (e.g.) Ascaris lumbricoides. This is an intestinal parasite in man. Male and female look different. Female is longer and straight. Male is shorter with a curved posterior end. Infection is carried on by contamination through water, vegetables and by the house fly.



Fig. 15.
Ascaris lumbricoides

**Phylum Annelida:** This phylum has animals with the following general features.

1. Body is cylindrical and marked both externally and internally into numerous segments.
2. All segments have more or less identical arrangement of organs. This is called Metamerism.
3. Body wall has both circular and longitudinal muscles.
4. A true coelom is present.
5. There is a closed blood vascular system with coloured blood due to haemoglobin dissolved in the plasma.
6. Excretion is carried on by special paired tubes called nephridia.

This phylum is divided into 3 main classes namely (1) Archi-annelida, (2) Chaetopoda and (3) Hirudinea.

*Class* (1). *Archiannelida* (e.g.) Polygordius:

This is a marine worm with clear internal segmentation but outwardly with faint markings only. There are no parapodia and no setae.

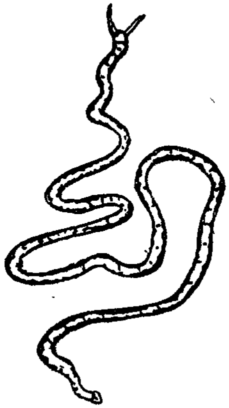


Fig. 16. Polygordius

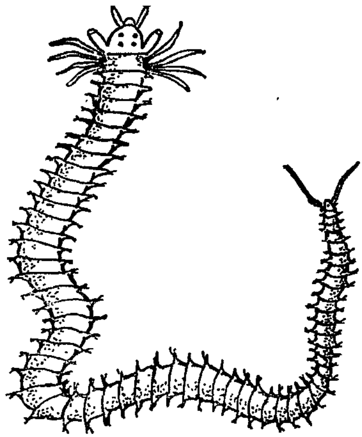


Fig. 17. Nereis

*Class* (2) *Chaetopoda:*

This is divided into 2 groups namely Polychaeta and Oligochaeta. Nereis represents polychaeta and earthworm represents oligochaeta. Nereis is a marine worm with a distinct head with tentacles and eyes. The body is flat and metamerically segmented. Each segment has a pair of parapodia with numerous setae, which help in locomotion and respiration. There is a larval stage in life history.

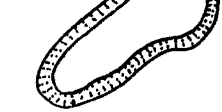


Fig. 18. Earthworm

Earthworm is terrestrial, living in moist soil in burrows. Body is cylindrical and metamerically segmented. Parapodia are absent; numerous setae are embedded in the skin which help in locomotion. Eyes are absent. Movement is by circular and longitudinal muscles. Excretion is by paired tubes called Nephridia. This animal is a hermaphrodite and sexual reproduction takes place. There is no larval stage.

*Class* (3). *Hirudinea* (e.g.) Leech:

This is an occasional external parasite, living on the blood of vertebrate hosts. It is mainly aquatic. There is an anterior and a posterior sucker. Body is made of 33 segments. Setae are absent. Animal is hermaphrodite and there is no larval stage.

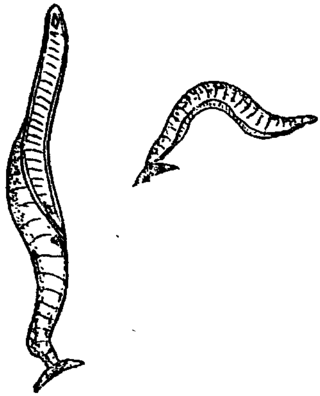


Fig. 19. Leech

**Phylum Arthropoda:** This is a very big phylum including a large number of animals. The animals in this phylum have the following common features:

1. Body is metamerically segmented, and shows bilateral symmetry.
2. There is a distinct cephalisation.
3. The body is covered by hard chitinous plates forming an exoskeleton.
4. Most of the segments of the body bear paired appendages.
5. The appendages are many jointed and hence the name Arthropoda.
6. Body cavity is a haemocoel or blood space.
7. Excretion is by Malpighian tubules or Green glands.
8. Eyes are generally compound eyes. Each eye is made of numerous units called ommatidia.
9. Cilia are absent in the animals.

10. Sexes are separate. Many arthropods show metamorphosis in the life cycle.

This phylum is divided into 5 classes namely (1) Crustacea, (2) Myriapoda, (3) Insecta, (4) Arachnida and (5) Onychophora.

*Class* (1). *Crustacea* (e.g.) Prawn:

This is aquatic. Body is divided into 3 regions namely cephalon or head, thorax and abdomen. The number of segments is definite. The head has 5, thorax has 8 and abdomen has 6. The cephalic and thoracic segments have a common dorsal shield known as carapace. All segments bear a pair of appendages each which are many jointed. There are sensory, feeding, walking and swimming appendages. Respiration is by gills. Sexes are separate. There are several larval stages in life history.

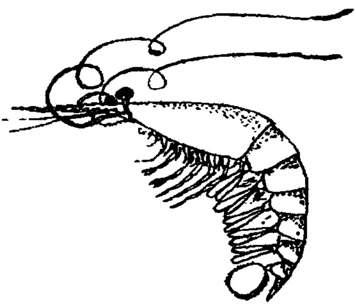


Fig. 20. Prawn

*Class* (2). *Myriapoda* (e.g.) Centipede and Millipede:

These are terrestrial animals. Body is many segmented. There is a distinct head with simple eyes and antennae. Segments bear a

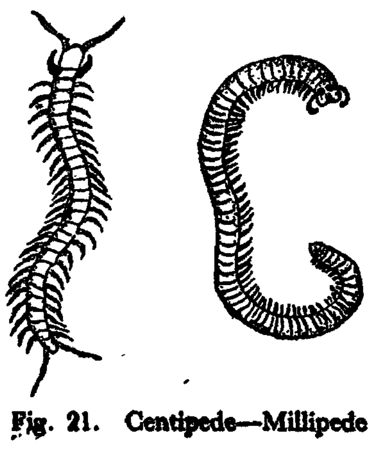


**Fig. 21. Centipede—Millipede**

pair of appendages each in centipede, and 2 pairs of appendages each in millipede. Centipede is carnivorous, nocturnal and has a pair of poison claws. Millipede is herbivorous, diurnal and has no poison claws. Respiration is by tracheal tubes which open to the outside by spiracles. Sexes are separate and there is no larval stage.

*Class* (3) *Insecta* (hexapoda). (e.g.) Cockroach, Grasshopper:

This is a very big class of Arthropoda and has several orders.

A typical insect has its body divided into a head, a thorax and abdomen. Head carries a pair of compound eyes, and a pair of antennae. Many organs in the mouth help feeding and they are adapted suitably for different diets of different insects. The thorax has 3 segments and usually bears 2 pairs of wings and 3 pairs of jointed legs. Abdomen has 10 segments with no appendages. Respiration is by tracheal system. Sexes are separate. There is usually metamorphosis in the life cycle.

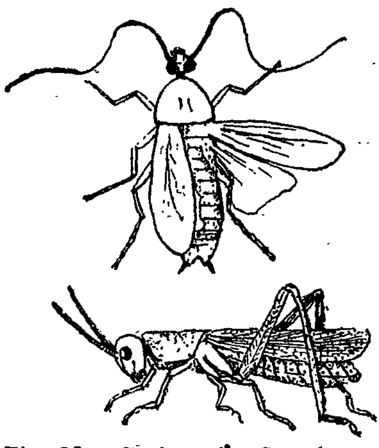


Fig. 22. Cockroach—Grasshopper

*Class* (4) *Arachnida* (e.g.) Spider, Scorpion, Tick, Mites:

These arthropods have 4 pairs of legs. The front part or prosoma of the body has 1 pair of chelicerae, 1 pair of pedipalps and 4 pairs of legs. Antennae are absent. Paired simple eyes are present. Respiration is by tracheae or book lungs. Some are

poisonous. In spiders the prosoma and opisthosoma are clearly separated. In ticks there is no such demarcation. Ticks are parasitic.

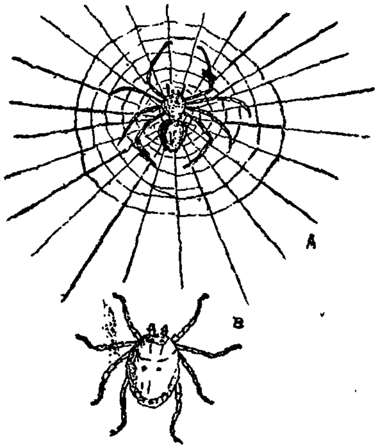



Fig. 23. A. Spider—B. Tick

*Class* (5). *Onychophora* (e.g.) Peripatus:

This class is now elevated as a sub-phylum. The animal has some annelidan and some arthropodan characters. Animal shows discontinuous distribution.



Fig. 24. Peripatus

**Phylum Mollusca:** This phylum has many animals which have the following general characters:

1. Animals are soft bodied and unsegmented.
2. The body is enclosed by a fold of skin called the mantle.
3. The mantle usually secretes a calcareous shell.
4. The locomotor organ is a muscular organ called the foot.
5. The respiratory organs are usually the gills or branchiae or a 'lung' in terrestrial forms.
6. Nervous system consists of several pairs of ganglia and their connectives.

The phylum mollusca is divided further into 5 classes namely (1) Amphineura, (2) Scaphopoda, (3) Pelecypoda, (4) Gastropoda and (5) Cephalopoda.

*Class* (1). ***Amphineura*** (e.g.) Chiton:

Animals are all marine. Body is bilaterally symmetrical. It is covered dorsally by 8 pieces of shell. There is a broad ventral foot.

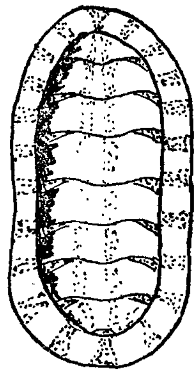


Fig. 25. Chiton



Fig. 26. Dentalium

*Class* (2). ***Scaphopoda*** (e.g.) Dentalium:

It is popularly called tusk shell. The body is elongated and lacks a distinct head. The animal is a marine form often burrowing in sand. There is a single tusk shaped shell.

*Class* (3). ***Pelecypoda*** or Bivalvia (e.g.) Lamellidens:

These animals are bottom dwellers in shallow waters. There

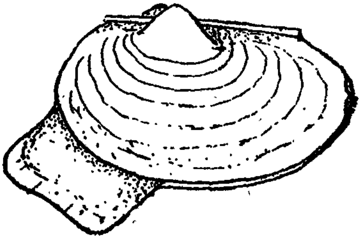


**Fig. 27. Lamellidens**

are two shells hinged together dorsally. There is a muscular foot in front which helps in locomotion. Animal feeds on micro-organisms that are swept in, by a ciliary current.

*Class* (4). *Gastropoda* (e.g.) Pila:

The animal has a spherically coiled shell. The foot is broad and has a creeping sole. The animal can withdraw into the shell and close up the opening with a lid called operculum. It has adaptations for aquatic and aerial respiration. The animal has in its mouth a rasping organ or a radula. Sexes are separate. There is no larval stage.

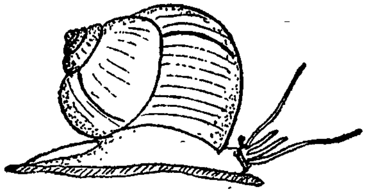


Fig. 28. Pila

*Class* (5). *Cephalopoda* (e.g.) Sepia:

This is a marine animal. The body is bilaterally symmetrical. There is a distinct head with prominent eyes and oral arms. Shell is internal. The foot is modified into oral arms and the siphon. Sexes are separate. There is no larval stage.

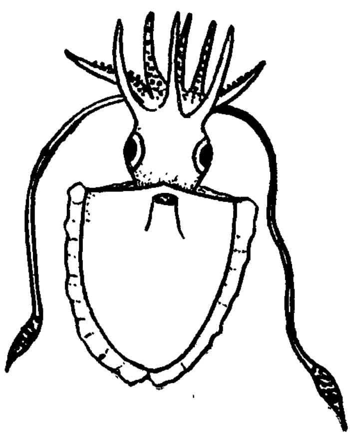


Fig. 29. Sepia

**Phylum Echinodermata:** This phylum comprises of animals with the following general characters:

1. All animals are marine.
2. Animals exhibit radial symmetry but the larvae show bilateral symmetry.
3. The skin is supported by calcareous plates or spicules and spines; hence the name echinodermata.
4. A peculiar system of canals, called water vascular system is present, in which sea water circulates.
5. The organs of locomotion are tube feet.
6. There are no definite excretory organs.
7. Respiration is by dermal branchiae.
8. Sexes are separate. There is a distinct larval stage.

The phylum is divided into 5 classes namely (1) Asteroidea, (2) Ophiuroidea, (3) Echinoidea, (4) Holothuroidea and (5) Crinoidea.

*Class* (1). *Asteroidea* (e.g.) Star fishes:

The animals have a central disc and 5 radiating arms. Mouth is ventral and anus is dorsal. Numerous tube feet are present on the ventral side of the arms, on either side of a groove. Skin is full of spines, gills and pedicelleriae.

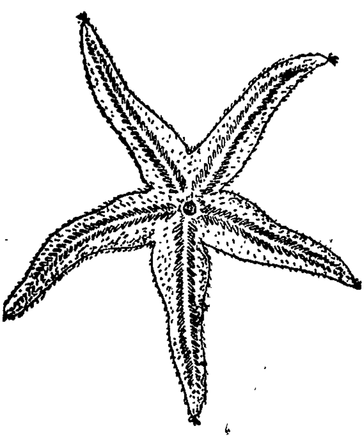


**Fig. 30. Star fish**

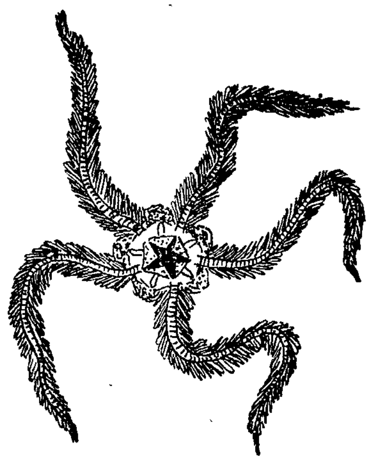


Fig. 31. Brittle star

*Class* (2). *Ophiuroidea* (e.g.) Brittle stars:

The central disc is small. The arms are long and narrow and they show independant movement.

*Class* (3). *Echinoidea* (e.g.) Sea Urchins:

These are almost spherical. The mouth is ventral. Numerous long spines project from the body through the shell.

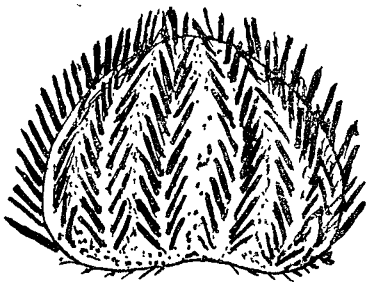


Fig. 32. Sea urchin

*Class* (4). *Holothuroidea* (e.g.) Sea Cucumbers:

These are found lying at the bottom of shallow reefs. skin appears smooth but has numerous spicules embedded in it.

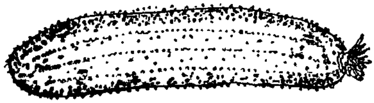


**Fig. 33. Sea cucumber**

*Class* (5). *Crinoidea* (e.g.) Sea Lily:

These are attached forms. The arms appear as the leaves of palm trees. There are no suckers on tube feet, and no pedicellariae.

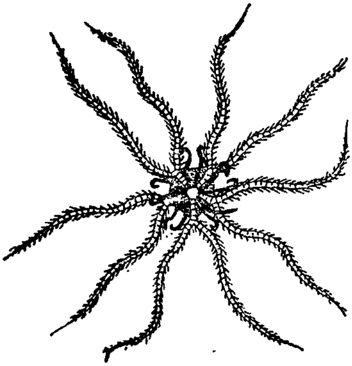


Fig. 34. Sea lily

**Phylum Chordata:** This is a very big group of animals, which differ from the previous phyla by certain major differences such as—

1. All animals have a median, dorsal, supporting rod called Notochord. This gives rise to backbone later, in higher chordates.
2. There are paired gill slits on the wall of the pharynx. These appear at least in embryonic stages.
3. The central nervous system is dorsal and tubular.
4. The heart is placed ventrally behind the pharynx.
5. There is a distinct hepatic portal system (Blood from the alimentary canal is taken to the liver and from there, it is again taken to the heart).
6. There is a post-anal tail.
7. Animals do not have more than two pairs of limbs (limbs may be absent, but never more than 2 pairs).
8. The respiratory pigment is found in the corpuscles of the blood.

This phylum has a subdivision called prochordates which include the Amphioxus and the Ascidian.

*Amphioxus* (*Branchiostoma*) *lanceolatus*:- This belongs to the division cephalochordata. The animal lives half burried in the sandy bottom of the sea. The body is about 1 to 2 inches in length. It creates a current of water through its mouth and feeds on micro organisms that come in with the water. The pharynx has numerous



Fig. 35. Amphioxus

gill slits. The endostyle, a special food capturing device is on the floor of the pharynx. The circulatory system is typical of a chordate animal. There is a long median notochord above the alimentary canal. A dorsal tubular nervous system is also present.

*Ascidian* **It represents** the division urochordata or tunicata. These are sedantary animals in the sea. The larva has a notochord in the tail region. Later this disappears. Water is taken in through the mouth along with micro organisms. The pharynx has numerous gill slits and a food capturing organ the endostyle. The circulatory system is peculiar because it flows in opposite directions alternately. Nervous system is very much reduced.

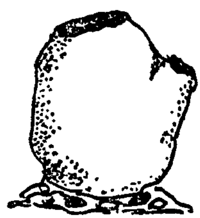


Fig. 36. Ascidian

The subdivision vertebrata or Craniata is divided into five big classes namely (1) Pisces, (2) Amphibia, (3) Reptilia, (4) Aves and (5) Mammalia.

*Class* (1) *Pisces* (e.g.) Mugeil oeur. (Mullet):

This includes cartilagenous fishes like Shark and bony fishes like Mullet. The fishes have the following general features.

1. All are aquatic.

2. Body is covered by dermal scales.
3. Respiration is by pharyngeal gills.
4. Locomotion is effected by fins.
5. All are cold blooded.
6. Most of them are oviparous (egg-laying).
7. The heart has only 2 chambers namely 1 auricle and 1 ventricle.
8. The brain has a pair of vascular sacs and a pair of inferior lobes.

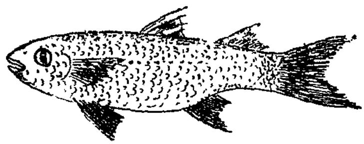


Fig. 37. Mugeil oeur (Mullet)

*Class* (2). *Amphibia* (e.g.) Rana hexadactyla (Frog):

This includes the toads, frogs, newts and salamanders, and limbless forms like icthyophis. The animals of this class have the following features.

1. Animals are capable of living in water and straying on land also.
2. The body is covered by a smooth skin full of glands to help cutaneous respiration.
3. Both aquatic and aerial respiration are possible because skin and lungs are respiratory. In early larval stages gills are also present.
4. The animals have 2 pairs of limbs except in the case of apoda or gymnophiana.
5. All are cold blooded.
6. Animals are oviparous.
7. The heart has 3 chambers namely 2 auricles and 1 ventricle.

8. The early stages of life requires aquatic environment. There is a metamorphosis.

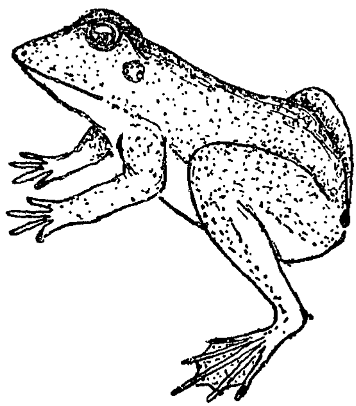


Fig. 38. Rana hexadactyla (Frog)

*Class* (3). *Reptilia* (e.g.) Calotes versicolor (garden lizard):

This class includes many animals like lizards, snakes, turtles, tortoises, crocodile and the tuatara. The animals have the general features listed below:

1. All are terrestrial animals in that they are adapted for it. (Turtles, crocodiles etc. have taken to water for feeding. They have to come out for breathing and breeding.)
2. Body is covered by epidermal scales.
3. Respiration is only by lungs.
4. Locomotion is by 2 pairs of limbs. The digits have claws. (In snakes limbs are absent.)
5. All are cold blooded.
6. Animals are oviparous.
7. The heart has 2 auricles and 1 ventricle which is imperfectly divided into 2.
8. The embryo develops a bag like, liquid filled, covering called amnion, in which the embryo floats..

The reptiles have organs for internal fertilisation.

10. Numerous teeth on jaw bones are found in both jaws.

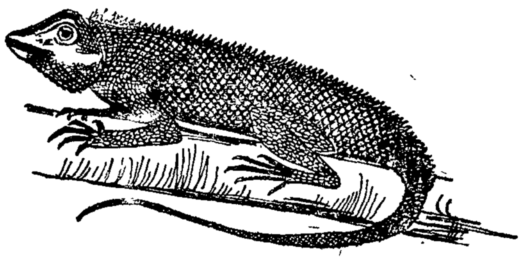


Fig. 39. Catoles versicolor (Garden lizard)

*Class* (4). *Aves* (e.g.) Columba livea (Pigeon):

All birds come under this class. They are characterised by the following:

1. Animals are terrestrial or arboreal.
2. Body is covered by feathers, which are of epidermal origin.
3. Respiration is by lungs which have air sacs attached to them.
4. The forelimbs are modified as wings for flight. The hind limbs are anteriorly shifted for balance. Digits have claws and adapted for perching.
5. Birds are warm blooded (have a constant temperature irrespective of the surrounding).
6. They are oviparous.
7. Heart has 4 chambers, 2 auricles and 2 ventricles.
8. There is a development of amnion.
9. Fertilisation is internal, though there are no organs for internal fertilisation. In females the right ovary and oviduct are abolished.

10. Teeth are absent in the jaws. Jaws are modified into beaks.
11. Many bones are fused together and some are porous.
12. Parental care is evident by the nest building, incubating and feeding the fledglings.

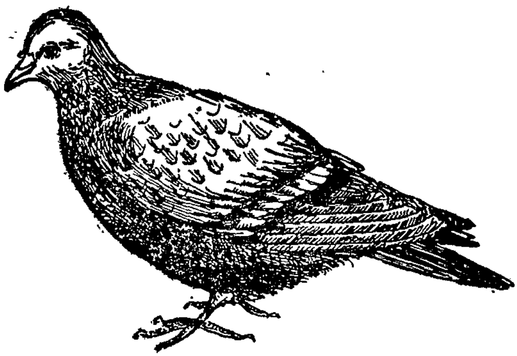


Fig. 40. Columba livea (Pigeon)

*Class* (5). *Mammalia.* (e.g.) Rattus rattus (Rat):

This class has numerous animals which have the following general characters:

1. Animals are terrestrial except few like whales, dugongs, seals etc.
2. Body is covered by epidermal hairs.
3. Respiration is only by lungs.
4. There are two pairs of pentadactyle limbs differently modified in different groups. Digits have nails.
5. Mammals are all warm blooded.
6. Mammals are viviparous (i.e.) they bring forth young ones which have developed inside the mother's body.
7. The young are fed by the secretion of mammary glands (hence the name Mammals).
8. Heart has 4 chambers namely 2 auricles and 2 ventricles.

9. There is a development of amnion during development.
10. Dentition is thecodont, heterodont and diphyodont.
11. There is a diaphragm separating the chest and the abdomen.
12. There is an external ear or Pinna on either side of the head.
13. The Urinogenital and anal openings are separate.
14. Parental care is evident.



Fig. 41. Rattus rattus (Rat)

Chapter III

# EUGLENA VIRIDIS

**Euglena viridis** is an unicellular organism found commonly in fresh water ponds and tanks, especially those that are rich in decaying organic matter The animal is placed in classification as follows:

| | | |
|---|---|---|
| *Kingdom* | — | Animalia |
| *Sub-kingdom* | — | Invertebrata |
| *Phylum* | — | Protozoa |
| *Class* | — | Mastigophora or Flagellata |
| *Sub-class* | — | Phytomastigna or Phytomastigophorea |
| *Order* | — | Euglenida |
| *Family* | — | Euglenidae |
| *Genus* | — | Euglena |
| *Species* | — | viridis |

**Structure:**

The animal is spindle shaped with a blunt anterior end and a pointed posterior end. The shape is almost constant because of the cell membrane which is also called the periplast or pellicle The nucleus is at the centre of the animal. The cytoplasm of the cell can be differentiated into an outer clear ectoplasm and an inner granular endoplasm The ectoplasm is more in a 'gel' state and the endoplasm is more in a 'sol' state. The anterior end of the animal has a deep depression called the gullet or cyto-pharynx. A long thread like structure called the flagellum or *mastix* arises from the base of the gullet. This whip like flagellum is really made of 2 fibres called axial filaments or axonemes. These arise from 2 granular bodies inside the pellicle, which are called the basal granules or *blepharoplasts.* The flagellum looks like an elongated cilium, in having 2 central fibres surrounded by 9 double fibres as seen in a cross section. The blepharoplasts are connected to the nucleus by a thickening of the cytoplasm called the *Rhizoplast*. There is a photoreceptive spot or light sensitive spot near the

anterior end of the animal. This is called the eye-spot or *stigma*. This contains granules of a carotin pigment called *hematochrome*.

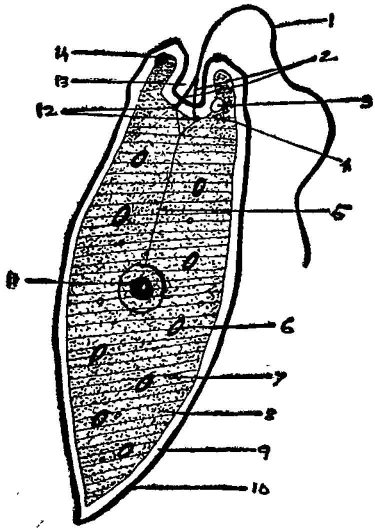



Fig. 42. Euglena viridis

1. Flagellum 2. Axoneme fibrils 3. Contractile vacuole 4. Formative vacuoles 5. Rhizoplast 6. Chromoplast 7. Myoneme fibrils 8. Endoplasm 9. Ectoplasm 10. Pellicle 11. Nucleus 12. Basal granules 13. Gullet 14. Eye-spot

There is a contractile vacuole near the gullet. It consists of a central reservoir and a number of small formative vacuoles around it. Very fine oblique striations are seen across the animal running on the surface. These are called *myoneme fibrils* and these are contractile. Inside the cytoplasm, there are numerous green plastids (chloroplasts) called chromatoplasts or chromatophores. These contain the green pigment chlorophyll characteristic of plant cells. Reserve food materials in the form of protein (pyrenoids) and starch (paramylum bodies) are also seen in the cytoplasm, sometimes in close association of the chromatoplasts.

Chapter IV

# MEGASCOLEX MAURITII

## (Earthworm)

The earthworm is a good representative of the coelomate animals. It occurs in moist soils in small burrows. The animal is generally nocturnal in habit. As the animal makes burrows in the soil, it helps aeration of the soil, which is very good for plants. That is why it is called "the friend of the farmer". It is placed in classification as follows:

| | | |
|---|---|---|
| *Kingdom* | — | Animalia |
| *Subkingdom* | — | Invertebrata |
| *Phylum* | — | Annelida |
| *Class* | — | Chaetopoda |
| *Subclass* | — | Oligochaeta |
| *Order* | — | Terricolae |
| *Family* | — | Megascolacidae |
| *Genus* | — | Megascolex |
| *Species* | — | mauritii. |

The body of the earthworm is cylindrical and is marked into numerous segments. The markings are not only external but also internal. All the segments have more or less the same arrangement of organs inside. This type of repeated arrangement in every segment is called *metamerism.* There is a true body cavity or coelom inside.

Any two segments are separated by a small constriction, called the intersegmental groove. There is a definite anterior and a posterior end. The mouth is in the centre of the first segment which is called the peristomium. Overhanging the mouth, in front of it, there is an upper lip like structure called the prostomium. The anus is in the centre of the last segment called the pygidium. The segments 14, 15, 16 and 17 secrete a hard ring like covering around themselves called the clitellum. Behind the clitellum the

number of segments is indefinite running to 80 to 100. Dorsally the intersegmental grooves behind the 10th segment bear small holes called dorsal pores, through which the body fluid exudes to keep the skin moist. The dorsal pores are absent in the region of the clitellum. The animal is a hermaphrodite. The male reproductive openings are found ventrally on the 18th segment, one—on either side. The female reproductive openings are found ventrally on the 14th segment often enclosed in a ridge. Small excretory openings called nephridiopores are present in some segments but they are too minute to be seen. All segments have small chitinous setae embedded in the skin. These can be extended or retracted by muscles.

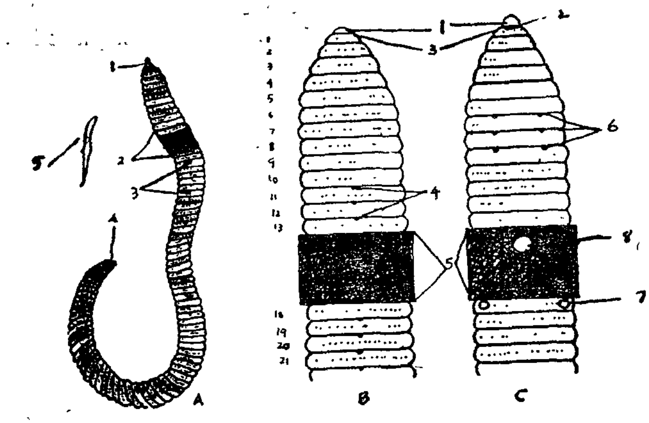



Fig. 43 .A. Earthworm
1. Mouth 2. Clitellum 3. Dorsal Pores 4 Anus
5. Body seta

B. Earthworm Dorsal view C. Ventral view
1. Prostomium 2. Mouth 3. Peristomium 4. Dorsal Pores
5. Clitellum 6. Spermathecal openings 7. Male openings
8. Female openings

A cross section of the earthworm shows the following details. There is a cuticle on the outside secreted by the underlying epidermis. This is protective in function. The epidermis supports several chitinous setae embedded in sacs. The setae are slightly bent rod like structures with a swelling in the centre. The alimen-

tary canal is surrounded by endodermis and muscle layers. The cavity between the body wall and the alimentary canal is called the body cavity or coelom. This contains blood vessels, nerve cords and nephridia.

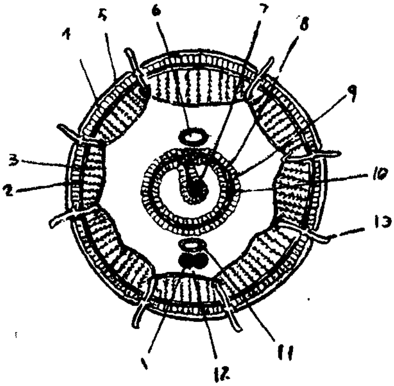



**Fig. 44** C.S. of Earthworm

1. Nerve cord 2. Circular muscles 3. Longitudinal muscles 4. Epidermis 5. Cuticle 6. Dorsal blood vessel 7. Typhlosole 8. Muscle layer 9. Chlorogogen cells 10. Intestine 11. Ventral blood vessel 12. Coelom 13. Body seta

## Chapter V

# PERIPLANETA AMERICANA

## (Cockroach)

The cockroach is a pest occurring in the dark corners and storerooms. This is a nocturnal insect hunting for its food at night. It is placed in classification as follows:

| | | |
|---|---|---|
| *Kingdom* | — | Animalia |
| *Subkingdom* | — | Invertebrata |
| *Phylum* | — | Arthropoda |
| *Class* | — | Insecta (Hexapoda) |
| *Order* | — | Orthoptera |
| *Family* | — | Blattidae |
| *Genus* | — | Periplaneta |
| *Species* | — | americana. |

The body of the animal is divisible into distinct regions namely the head, neck, thorax and abdomen. The head is pear shaped

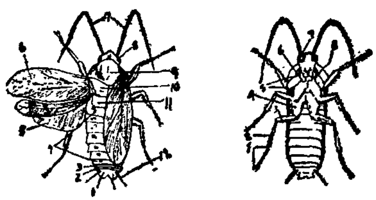


Fig. 45 Cockroach

A. Dorsal view

1. Anal styles 2, 3, 8, 9. Segments 4. Abdomen 5. Hindwing 6. Forewing 7. Antennae 8. Eye 9. Prothorax 10. Mesothorax 11. Metathorax 12. Anal cerci

B. Ventral view

1. Tarsus 2. Tibia 3. Femur 4. Coxa 5. Trochanter 6. Maxillae 7. Eye 8. Labial Palp

and it is held at right angles to the axis of the body. It is covered by hard chitinous plates. There are two large compound eyes on the dorsal side of the head. Each compound eye is made of numerous units called *ommatidia.* So the cockroach has an efficient mosaic image of its objects. There are two long annulated whip like structures arising from the head. These are called *antennae* which are used as feelers. Near the base of the antennae there are two soft white spots called *fenestrae* which are useful to find differences in temperature. The two plates covering the head on top, between the eyes, are called *epicranial plates.* The front of the head has a broad central plate called *Clypeus* or *Frons.* The sides of the head are covered by two plates called *genae.* The upper lip or *labrum* hangs in front. There are various organs in the lower part of the head constituting the mouth parts.

The neck is a narrow cylindrical part supported by several ring like thickenings made of chitin. These are called the *cervical sclerites.*

The thorax is made of three segments, namely Prothorax, Mesothorax, and Metathorax. Each segment has a dorsal plate, called *tergum*, a ventral plate called *sternum* and at the sides a membranous *pleura.* The thorax bears two pairs of wings dorsally and three pairs of legs ventrally. The first pair of wings or forewings are on the mesothorax. These are not useful for flight but serve to cover the hindwings and the abdomen. So these are also called *tegmina* or *elytra.* The second pair of wings or hindwings are on the metathorax and they are membranous. These are used in flight.

Each segment of the thorax bears ventrally one pair of legs. The legs are made of many joints (hence the name *Arthropoda*). Each leg has the following joints namely *Coxa, trochanter, femur, tibia*, and a terminal 5 segmented *tarsus.* The last segment of the tarsus bears a pair of claws and a soft pad called *pulvillus.* The tibia and tarsus bear many stiff bristles which are useful for clean ing the body.

The abdomen of the cockroach has ten segments. Each segment has a dorsal plate called tergum and a ventral plate called sternum. At the sides, there are pleural membranes. The last segment bears a pair of annulated projections called *anal cerci.* In the males, there is an additional pair of projections called *anal styles.* These are absent in the females. The abdomen is broader

in the females and narrower in males The sternum of the 7th segment in the abdomen is cleft in the female but it is entire in the male.

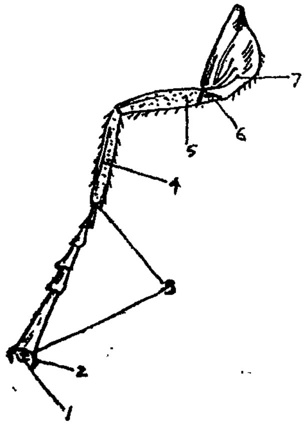



Fig. 45 Cockroach—Leg

1. Pulvillus 2. Claw 3. Tarsus 4. Tibia 5. Femur 6. Trochanter 7. Coxa

**Chapter VI**

# MUGEIL

**External Morphology:** Mugeil is popularly known as Mullet. It is a common edible fish found in the seas, estuaries, and brackish waters of India. There are several species of mullets. The more common ones are Mugeil cephalus, Mugeil parsia, Mugeil cunnesius etc. They are herbivorous forms. Some of them feed on the mud present at the bottom. They develop to a length of 6 to 12 inches.

The body is typically fish-like-streamlined. This is meant for breaking through the column of water. The body can be divided into three regions, namely, the head, trunk and the tail. The head is slightly depressed. The entire body is covered by overlapping scales resembling the arrangement of the tiles on a roof. The scales are developed from the dermal region of the skin. The scales are of the Ctenoid type. The scales are characterized by concentric lines and they are bisected by radiating ridges The free ends of the scale are produced into spines. The presence of spines is a characteristic feature of Ctenoid scale

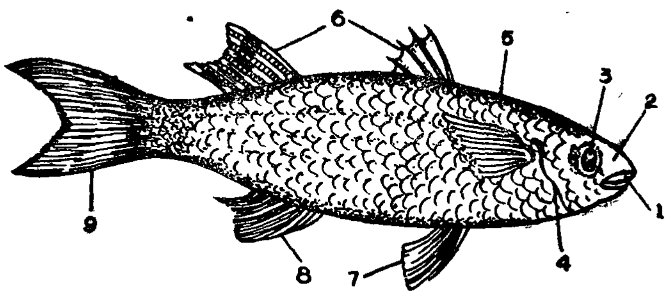



Fig. 47 Mugeil external features

1 Mouth 2. External nostrils 3. Eye 4. Operculum 5. Pectoral fin 6. Dorsal fins 7 Pelvic fin 8. Anal fin 9. Caudal fin

The head has the terminal mouth, a pair of nostrils and a pair of eyes on the lateral sides. The eyes are without the eyelids except for the transparent nictitating membrane. The mouth is bounded by upper and lower jaws. The jaws are devoid of teeth. Mouth leads into the buccal cavity. The posterior end of the head has a pair of semicircular flap like gill covers or opercula. These cover the delicate gills and thus afford protection to them.

The trunk is laterally compressed and it supports paired and unpaired fins. Fins are characteristic of fishes and are the organs concerned with locomotion. The fins are of two types, namely, the paired and the unpaired fins. Both types of fins are membrane-like structures supported internally by bony elements termed as fin rays. The paired fins include the pectorals and the pelvics. The pectoral fins are present behind the opercula one on either side. The pelvic fins are ventral in position close to the pectoral fins. The unpaired fins include two dorsal fins, the anal or the ventral fin and the caudal fin. The two dorsal fins are found on the mid-dorsal line of the trunk. The first dorsal fin is supported by 4 to 5 bony fin rays. The tips of the bony fin rays are spiny. The second dorsal fin is close to the caudal fin. It is supported by soft fin rays. The anal fin or ventral fin, as the name indicates is present close to the anus. It is also supported by soft fin rays. The caudal fin supports the tail. It is of the homocercal type. It is formed of a dorsal and ventral lobe equal in size. Internally the fin rays are more well developed on the ventral side. The dorsal and ventral fins by their oscillating movements serve to balance the body and prevent the fish from rolling on to its sides. The caudal fin by its lashing movements serves to change the direction of swimming. The pectoral and the pelvic fins by their movements serve to steer the fish forwards. Anus is situated about two thirds from the anterior end. The urinogenital apertures are present behind the anus.

## Chapter VII

# RANA HEXADACTYLA

The common frog is very often found in or near water. It belongs to the class Amphibia. The Amphibia occupy an intermediate position between the fishes and reptiles showing adaptations for life in water and on land. There are several species of frogs, the commonest of which are Rana hexadactyla characterised by six toes in the hind limbs. (hexa—six ; dactyl—digit) The sixth toe being invisible as it is concealed beneath the skin. Rana cyanophlictis and Rana tigrina are characterised by stripes on the skin.

**External morphology.**—The body of frog is compact and is divided into two parts, namely the head and the trunk. A distinct neck is absent. A tail is also absent in the adults. The body is covered over by a loosely attached smooth slimy moist skin. It is totally devoid of any skeletal structures. The head is triangular in shape with a wide mouth in front and it merges invisibly with the trunk. The mouth is bounded by upper and lower jaws. On the dorsal side of the head close to the tip of the snout is a pair of external nostrils which can be closed or opened by thin flap like extensions of the skin. Behind the nostrils two prominent eyes are present one on each side of the head. Each eye is protected by upper and lower eyelids. The upper eye lid is thick, fleshy and immovable and has the same colour as the surrounding skin. The lower eye lid gives origin to a thin transparent nictitating membrane which functions as a protective structure. It can be drawn over the eyes and it keeps the eyes moist and clean when the animal is on land and protects it when it is in water. Behind each eye there is dark circular patch of stretched skin known as the tympanic membrane or the ear drum.

The trunk is broad and somewhat flattened and bears two pairs of limbs on the sides. The fore limbs are short and are situated anteriorly while the hind limbs are longer admirably

adapted for jumping and swimming. Each fore limb consists of an upper arm or brachium, the fore arm or antebrachium and the hand or manus. The hand is made up of the wrist or carpus, the palm or metacarpus and the fingers or digits. There are only four fingers in each fore limb the finger corresponding to our thumb or pollex being absent. Each hind limb consists of three divisions, namely the thigh or femur, the shank or crus and the foot or pes. The foot is made up of the ankle or tarsus,

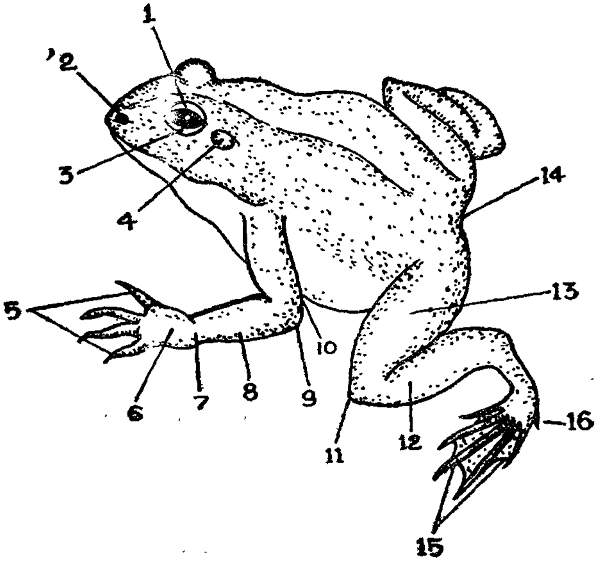



**Fig. 48** Frog—External features

1. Upper eyelid 2. External nostril 3. Lower eyelid 4. Tympanum 5. Fingers 6. Palm 7. Wrist 8. Fore arm 9. Elbow 10. Upper arm 11. Knee 12. Shank 13. Thigh 14. Cloaca 15. Web 16. Calcar

the instep or metatarsus, and the toes or digits. There are five webbed toes in each hind limb which aid in swimming. The fourth toe is longest, the third and fifth toes are equal in size, the second is shorter than fifth and the first or inner most toe the shortest of all. At the posterior end of the trunk and situated dorsally between the bases of the hind limbs is a small aperture called the cloacal aperture. The frog is said to be a

tetrapod since it has two pairs of limbs and the limbs are described as pentadactyl since they bear five digits each.




Fig. 49 Frog—Sexual dimorphism: Male

a. Head b. Hand of a male frog

1. Vocal sac 2. Nuptial pad

The frog exhibits sexual dimorphism. The male can be distinguished from the female during the breeding season by the presence of a pair of vocal sacs near the angles of the jaws and by the presence of a thick pad of tissue on the index finder called the nuptial pad. The latter helps the male to grasp the female during copulation.

## Chapter VIII

# RATTUS RATTUS

**External morphology:** It is a common household mammal. The related form, namely the field rat Gerbillus indicus, is found in the paddy fields. The house rat has a naked scaly tail while the field rat has hairy and bushy tail.

The body is divisible into a head, trunk and a tail. The body is covered by hairs which are epidermal in origin. The presence of hair is a characteristic feature of the mammals.

The head is conical in shape and front part is distinguished as snout. The tip of the snout has a pair of external nostrils and a few hair-like structures termed, the vibrissae. These are sensory in function. The mouth present at the tip of the snout is bounded by fleshy upper and lower lips. This is a characteristic feature of mammals. A pair of well developed eyes are present on the lateral sides of the head. Each eye is supported by an upper and a lower eye lid and a nictitating membrane. The eyelids are supported by eye lashes. The presence of eyelashes are characteristic of mammals. A pair of funnel shaped cartilagenous pinnae are present, meant for receiving the sound waves. The pinnae lead into a tube called the external auditory meatus at the base of which is the tympanum. The presence of pinnae is a characteristic feature of mammals.

The trunk is divisible into an anterior bony thorax bounded by sternum and the ribs and a posterior soft walled abdomen. Trunk on the ventral side in the females has small prominences termed as teats. They are characteristic of mammals. The teats are small and undeveloped in the males. In the males a pair of scrotal sacs and a muscular penis are present at the posterior end of the trunk. The scrotal sacs enclose the testes. This is a characteristic feature of mammals. Anus is situated at the base of the tail. The urinogenital aperture is found on the ventral side in front of the anus. The space between the anus and the urinogenital aperture is the perineum. A pair of

perineal pouches are present one on either side of the anus. The trunk supports a pair of fore and hind limbs. The division of fore limbs and hind limbs are similar to that of the frog. The fore and the hind limbs are provided with five fingers and five toes respectively. Tail is elongated and ringed. Rat is a viviparous form giving birth to young ones.

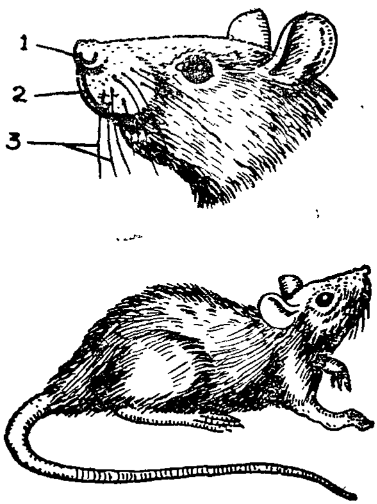



Fig. 50 Rat—External features

1. External nostril, 2. Cleft upper lip, 3. Whiskers.

## Chapter IX

# GENERAL ORGANISATION OF ACELLULAR ACOELOMATE PSEUDOCOELOMATE AND EUCOELOMATE ANIMALS

The unicellular animals of the phylum protozoa, are classified as acellular animals. This is because, the animals are not mere single cells. They are independent organisms, showing all the details of all activities. The parts of the cells working as microscopic organs are spoken of as organelles.

The next higher group of animals represented by the coelenterates are diploblastic animals, that is, their bodies are constituted by two layers of cells with a paste like Mesoglea in between. The only cavity inside the animals, represents the alimentary cavity or enteron and the body cavity or coelom. That is why it is called coelenteron.

All the other groups of animals are constituted by three main layers of cells namely Ectoderm or outer layer, Endoderm or inner layer and a third layer called Mesoderm, in between the other two layers. So these animals are called the Triploblastic animals.

Among the triploblastic animals, there are three main types namely (1) Acoelomate (2) Pseudocoelomate and (3) Eucoelomate animals.

**I Acoelomate animals :** Many organisms like the flat worms (platyhelminthes) and probosis worms have no body cavity or coelom. The space between the outer ectoderm (the bodywall) and the gut lined by endoderm is occupied by loosely arranged mesenchyme cells. This mass of cells is also called parenchyma.

**II Pseudocoelomate animals :** These animals like the rotifers and round worms have a body cavity in between the body wall and the gut. But this cavity is not a true coelom. This

represents the embryonic blastocoel space. The organs lying in the cavity are not covered by a layer of peritoneum. In the round worm ascaris the space is occupied by the ramifications of protoplasm of a large single cell. So the body cavity is called a pseudo coelom, as this is not given rise to by the mesoderm, as it is in the true coelomate animals.

**III Eucoelomate animals:** (Animals having true coelom) A true body cavity or coelom is given rise to by the Mesoderm of the embryo. A space is created in the middle of the mesoderm. This space is lined all round by a layer of mesoderm cells called the peritoneum. All the internal organs are having this protective covering layer of peritoneum. Thus all organs are placed or located behind the peritoneum.

The three different conditions namely Acoelomate, pseudo-coelomate and Eucoelomate organisations are represented in the diagram below.

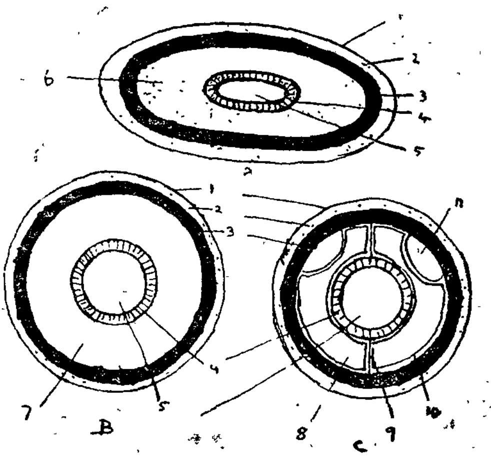



Fig. 51 A—Acoelomate B—Pseudo coelomate
C—Eucoelomate organisation

1. Cuticle 2. Epidermis 3. Muscle layer 4 Gut
5. Enteron 6. Mesenchyme 7. Pseudocoel 8. Coelon
9 Mesentery 10. Peritoneum 11 Internal organ

## Chapter X

# ORGANIZATION OF THE CELL

Living matter is called protoplasm. Typically it is more or less viscous, transparent and is a complex mixture of many substances. It may contain materials which may be unnecessary for life and other non—living substances such as fat or starch particles. But, whenever the term protoplasm is used, it refers to a unit of matter which manifests the characteristics of Life.

Protoplasm is typically maintained in units called cells which are the basic organizational units of life. The cell can be defined as the biological unit of activity. It is the smallest portion of the organism that exhibits the range of properties associated with living matter. It is delimited by a semipermeable membrane and is capable of self-reproduction in a medium free of other living systems. Some animals and plants consist of only one cell (unicellular). A great majority of the organisms are multicellular.

**General Structure and function of the cells:**

Though the cells may vary superficially according to different functions, most cells exhibit certain fundamentals of structure and function.

1. A living cell is bound by a membrane which is usually about 100A° thick (1 Angstrom $= 10^{-8}$cm). (Tables I and II). This membrane is always characterised by definite selectivity as to penetration by foreign substances, permitting passage to some and acting as impassable barriers to others.

2. Division of the cell into nucleus and cytoplasm.

3. Cytoplasmic inclusions such as mitochondria, lysosomes, centrosomes, ribosomes etc.,

4. Membrane systems of cytoplasm called endoplasmic reticulam and Golgi apparatus.

5. In higher organisms the nucelus is separated from the cytoplasm by the nuclear membrane. The nucleus contains the

important chromatin filaments of deoxyribonucleic acid (DNA). These filaments appear as distinct chromosomes during cell division.

The functional common features exhibited by the cells are·

1. They utilize energy from outside sources to organize atoms and molecules from the external environment and synthesize macromolecules typical of their own structure.

2. They perpetuate information for their own synthesis through repeated cycles of information.

3. They control their internal environment in such a way as to create the most suitable conditions for their metabolism.

4. They regulate their component reactions so that these work in harmony.

**TABLE I**

| | *Method* | *Dimensions of Structures that can be seen* | *Structures that can be seen* |
|---|---|---|---|
| 1. | Unaided eye and simple lens | 0.1mm (100 and larger) | Organs |
| 2. | Light microscopy | 100 to 10 | Tissues |
| 3. | X-ray microscopy | 10 to .2 (2000 A°) | Cells, bacteria |
| 4. | Polarisation and Electron microscopy | 2000A° to 0.2° | Cellular structures |
| 5. | X-ray diffraction | Smaller than 10A° | Arrangement of atoms. |

**TABLE II**

$$1 \text{ micron } (\mu) = \frac{1}{1000} \text{ mm or } 10{,}000 \text{ A}^\circ; \text{ or } 1000 \text{ m}\mu$$

$$1 \text{ millimicron } (\text{m}\mu) = \frac{1}{1000000} \text{ mm or } \frac{1}{1000} \mu \text{ or } 10 \text{ A}^\circ$$

$$1 \text{ Angstrom } (\text{A}^\circ) = \frac{1}{10000000} \text{ mm or } \frac{1}{10000} \mu \text{ or } \frac{1}{10} \text{ m}\mu$$

**Cellular differentiation:**

In single celled animals, all the functions of life are carried out in one cell. In multicellular organisms, groups of cells are specialized in their functions. Such specialised cells are said to be differentiated. In general, the cells that are present early in the development of an individual are relatively undifferentiated.

The circumstances which give rise to cyto-differentiation are little understood. The nucleus is generally assumed to be the same in all generations of cells. The constituents of cytopalsm may be altered and they are followed by changes in the cytoplasmic chemical processes resulting in functional and anatomical differentiation of cells.

Specialization of function of cells is generally accompanied by relative loss of other functions. For example, many cells do not multiply following differentiation as in nerve cells—which after a relatively young stage do not reproduce but may continue to grow by increasing in size. Some types of cells however, continue to grow even in the older individual, e.g. certain cells of the skin, of the reproductive system etc. In continuously growing tissues of this kind, the finally differentiated cells do not however reproduce. Thus it may not be always possible to demonstrate in any particular cell, all types of cellular function that living things are supposed to show.

Occasionally, cells regain the lost ability to reproduce. They lose their differentiated condition and begin to grow and reproduce in an unorganized manner. The various cancers are examples of this condition.

**Differentiation of tissues:**

The fertilized egg, called a *zygote,* is really a one-celled organism, and from it develops a complete animal with all its structures and functions. The major process which makes it is *differentiation* by which the various cells become unlike. Tissues are differentiated by *histogenesis.* Five major tissues are differentiated; from all three germ layers; (1) epithelial tissue from ectoderm (2) connective or supporting tissue, from mesoderm (3) Muscle tissue from mesoderm; (4) nervous tissue from ectoderm; and (5) vascular tissue from mesoderm. A *tissue* is a group of similar cells (together with associated cell products) specialized for performance of a common function. The study of tissues is *Histology.*

Chapter XI

# THE CELL

The cells are of numerous varieties but all the cells of living organisms have certain common basic structural and chemical properties. So it is convenient to describe a 'typica cell' either of an animal or of a plant. All cells have the following general structural elements.

1. The cells are limited by a cell membrane or plasma membrane.

2. The cell contents show a distinot Nucleus and surrounding cytoplasm.

3. Numerous organelles are present in the cytoplasm such as chloroplasts (in plant cells) Mitochondria, lysosomes, centrosome (in animal cells), endoplasmic, reticulum, ribosomes, vacuoles golgi apparatus etc.

4. The Nucleus is clearly enclosed by a nuclear membrane in all organisms (Eucaryotes) except a few lower level organisms like Nostoc Bacteria etc. (Procaryotes). The Nucleus contains Chromatin filaments made of DNA, which condense to form chromosomes during the cell divisions. Nucleus also contains the Nucleolus rich in RNA.

The discovery of Electron microscope has helped us to understand the ultra structure of the cell organelles and their function. Let us examine the various parts of the cell.

**1. The Plasma membrane :** The study of this membrane reveals that it is made of three layers namely an outer protein,

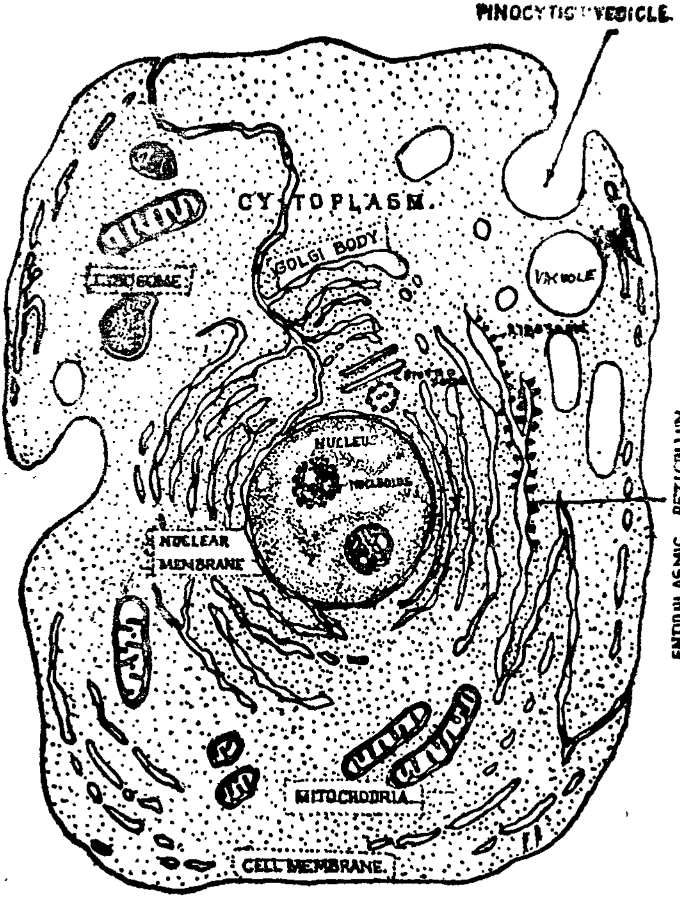



Fig. 52 Ultra structure of the cell

a middle lipid and an inner protein layers. The middle lipid layer actually has two tiers opposing each other as seen in the diagram.

The cell membrane is about 75 A thick. This type of trilaminar structure was described by Robertson and he called it as unit membrane. Later, this has come to be called sub-

unit membrane as the arrangement repeats itself. Still later it was assumed that there are specific gaps or pores in the

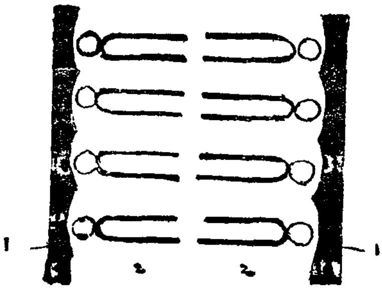



Fig. 53 Cell membrane (Model)

membrane. The plasma membrane is not smooth throughout the entire surface. It has minute projection called microvilli, or finger like extension called inter digitations or has inner thickened filaments which are known as desmosomes.

The cell membrane or plasma membrane serves the following purposes:

1. It limits the cell and maintains the shape of the cell and protects it.

2. It is permeable to certain fat soluble substances.

3. It can take in bigger particles by pinocytosis or phagocytosis.

4. It can take up ions even against the concentration grádient by a process called Active transport by spending energy.

5. It has a low surface tension and is electrically resistant; due to lipid.

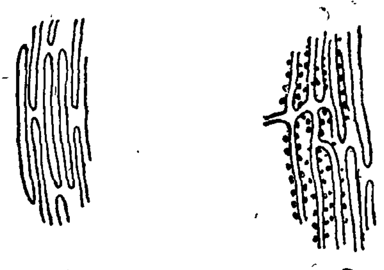
6. It is osmotically active being a semi-permeable membrane and therefore maintains the osmotic concentration of the cell.

The plasma membrane therefore controls the entry and exit of many substances into or out of the cell. Passive diffusion

osmotic diffusion and active transport are the mechanisms involved in maintaining the environment of the cell suitable for its functioning. The plasma membrane is also excitable and the impulse travels through it as in the case of nerve cells.

2. **The Cytoplasm :** This is a viscous substance colloidal in nature. This can be in two states namely 'sol' and 'gel' states. The 'sol' state is a more liquid form and the 'gel' state is more like a semisolid. The two states are inter changeable. Usually the outermost region is in the 'gel' state and the inner mass is in the 'sol' state. The cytoplasm contains the various organelles of the cell

3. **The endoplasmic reticulum :** The substance of the cytoplasm can be seen traversed by a net work or reticulum of canal like structures. These extend from the outer plasma membrane to the nuclear wall. These canal like structures are extensively branched and inter-connected. In some places these structures are bordered with granular bodies called ribosomes. Such a reticulum is called rough endoplasmic reticulum. If the granules are absent, then it is called smooth endo-



A B

Fig. 54 Endoplasmic reticulum

plasmic reticulum. The endoplasmic reticulum is prominent in secretory cells. The membranes forming the reticulum are similar in structure to the plasma membrane.

The functions of the endoplasmic reticulum are

1. **Involvement in protein synthesis and transport of ions.**

2. Intracellular transport of secretions or products.
3. Source of origin of other membranous structures in the cell.

Besides, fragments or small vesicles of endoplasmic reticulum appear as microsomes in the cytoplasm.

4. **The Ribosomes** : Distributed in the cytoplasm, especially attached to the endoplasmic reticulum are granular bodies called ribosomes. These are found to be made of two units, a bigger and a smaller unit (They can be separated by ultra centrifugation technique). The ribosomes are found to be made of RNA.

The ribosomes are associated in the function of protein synthesis. They are the places where protein is synthesised (by linking together of amino acid sequences) as per the directions received from the nuclear DNA, through the template RNA.

5. **The Golgi apparatus** : An Italian scientist by name Camilo Golgi discovered these structures in 1898. These appear as flattened sacs and saccules or small vesicles. These have been given different names such as dictyosomes, lipochondria, canalicular system, internal reticulum apparatus, trophispongium etc.




Fig. 55 Golgi bodies
1. Flattened sacs 2. Vesicles

The Golgi apparatus is usually found above the nucleus, surrounding the centrosome. It consists of double membranes enclosing cavities. There may be minute vesicles nearby, perhaps separated off from the flattened sacs or cisternae. The Golgi bodies arise either by division of pre-existing ones or they arise newly. Sometimes they arise from endoplasmic reticulum. These bodies contain lipid some carbohydrates and protein and some enzymes.

The Golgi apparatus is functionally connected with secretory products of the cell such as muco polysaccharides, gluco protein, lysosomic enzymes, and the acrosome in the head of the sperms.

6. **Mitochondria (chondriosomes) : The mitochondria are** sausage shaped membrane bound organelles found distributed in the cytoplasm. These organelles are connected with respiratory metabolism of the cell where the food is oxidised and energy is released along with $CO_2$ and $H_2O$. That is why these are called the 'power houses' of the cell.

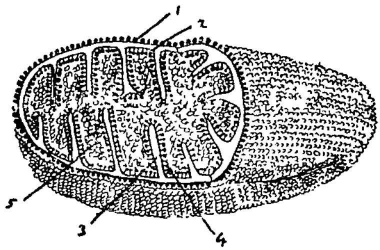



Fig. 56. Mitochondria

Each mitochondria has two membranes for its covering. The outer membrane is almost smooth. The inner membrane is projected inwards as shelves or partitions called cristae. The enclosed space inside the mitochondrian is called the matrix. If more cristae are found than the capacity of the mitochondrian for oxidative reactions is more. Arranged on the cristae are numerous electron transport particles. These electron transport particles are arranged in definite sequences. These are seats of enzymatic activity.

The break down of glucose takes place in two steps. The first step called glycolysis takes place outside the mito chondria. It is anaerobic. The phosphorylated glucose is broken down to pyruvic acid. The second step which is aerobic takes place inside the mitochondria. This step is a cyclic reaction involving many enzymes and is called the Krebis cycle or Tri carboxcylic acid cycle or citric acid cycle. As the end products of this cycle energy, $CO_2$ and $H_2O$ are formed. Because many

enzymes are contained inside the mitochandria, these are called 'enzyme packets'

7. **Lysosomes** : These are small vesicles found in the cytoplasm. These contain powerful enzymes. Each lysosome is surrounded by a lipoprotein membrane. The powerful enzymes help the cell to digest food taken by pinocytosis or phagocytosis. In aged cells, the enzymes are released by the rupture of the wall of the lysosomes and the cells disintegrate. These organelles are believed to play an important role during metamorphosis of animal (ie) in destroying old tisues.

8. **The Centrosome** : These organelles are present in all animal cells, which are capable of division. Each centrosome is

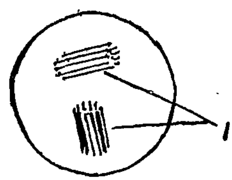



Fig. 57 Centrosome

a spherical body containing two centrioles inside. Each centriole appears, under electron microscope as a cylindrical bundle of fibre. There are two fibres in the centre and nine surrounding them. The two centrioles are usually at right angles to each other. It is of interest to note that the structure of the centriole bears a close resemblance to the arrangement of fibres inside a flagellum on cilium.

The centrosome initiates the cell division. The centrioles are involved in the formation of spindle fibres and astral rays. These are made of protein molecules with S. H. bonds.

9. **Plastids** : These are characteristic of plant cells. Each plastid has an outer membrane and a central matrix. In the matrix are long plates called lamellae and in between them, there are stocks of smaller plates called thylakoids. The

grouping of thylakoids appear as grana. The surface of the thylakoid carry quantosomes. There are different types of plastids such as green chlroplasts, coloured chromoplasts, and white leucoplasts. The colour ofcourse is changeable from one to another. The plastids are centres of active synthesis of food and storage.

10. **Nucleus** : The nucleus is also called karyosome as it takes up quickly any colomation given to the cell. It was Robert Brown (1833) who identified the nucleus first. It plays an important role in cell division and fertilisation. Cells with a well defined nucleus are called Eucaryote cells. In some primitive forms like Nostoc, Bacteria etc the nucleus is indistinct-without a nuclear membrane. These cells are called procaryote cell. Usually every cell has only one nucleus but there are exceptions.

The nucleus has a nuclear membrane inside which there is a viscous fluid called nuclear sap. A tangled mass of thread like structures called the chromatin network is contained inside the nucleus. Besides there is one nucleolus.

The nuclear membrane is like the plasma membrane of the cell but here it is made of two membranes with a small space inbetween. Here and there, there are small pores in the nuclear membrane to facilitate exchange of substances between cytoplasm and nucleus. At the time of the cell division the nuclear membrane disappears and is reorganised after the division.

The nuclear sap is a homogenous ground substance in which the chromatin reticulum lies. It is made of non-basic protein. There is no nucleic acid in the sap.

The chromatin material appears as a network during the interphase of the cell division. At the start of the cell division the chromatin material condenses and coils to form definite structures called chromosomes. Chemically the chromatin is made of DNA, histones and residual proteins. There are two types of chromatin namely the euchromatin and hutero chromatin. The euchromatin contains the genetic material or genes and does not stain deep. The hetero chromatin is devoid of genes but colours dark. This has a higher RNA content.

The Nucleolus was discovered by Fontana in 1781 and named Bowman in 1840. The nucleolus is a spherical body without a limiting membrane. It is seen to contain certain vacuoles. The nucleolus is surrounded by heterochromatic substances. The nucleolus contains a filamentous part called **Nucleolonema** and a ground substance called pars amorpha rich in RNA. The nucleolus undergoes cyclic changes, disappearing at the prophase and reappearing during telophase of the cell division. It is formed from the hetero chromatic region of the chromosomes, called Nucleolar organisers. Materials have been seen moving from the nucleolar region into cytoplasm. RNA is manufactured and moved into cytoplasm for the purposes of protein synthesis.

**Chromosomes :** Chromosomes are condensed chromatin material. They are definite in number in each cell of a species. All chromosomes have a primary constriction called

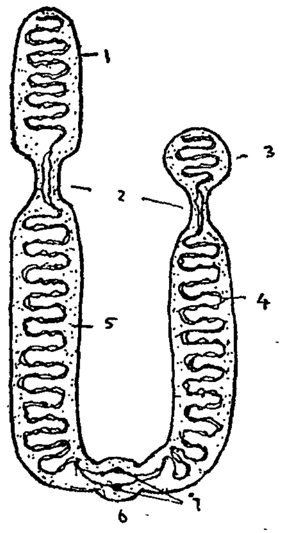



Fig. 58 Chromosome

1. Outer membrane 2. Secondary constriction 3. Satellite 4. Chromonemata 5. Matrix 6. Primary constriction 7. Kinetochore

centromere or kinetochore. This represents the point of attachment of the spindle fibre during cell division. Its position on the chormosome helps classification of chromosomes into (1) Metacentric-when the centromere is at the centre (2) Telocentric - when the centromere is terminal (3) Submeta centric - when the centromere is sub terminal - a little behind the end and (4) Acrocentric - when it is at the tip. The chromosomes also have a secondary constriction or nucleolar gap. The part of the chromosome beyond this gap is often called the satellite. Some chromosomes may lack the satellite region.

During cell division (Metaphase) the chromosomes split longitudinally into two halves called chromatids. Each chromatid may be seen to be formed by one or more chromonemata These have thickened areas called chromomeres. The chromatids may be formed by 16 to 32 chromosome fibrils coiled or super coiled to thicken. In sexually reproducing animals the body cells have a diploid set of chromosomes and the gemetes have a haploid set The sex chromosomes are called X and Y Chromosomes and the others as autosomes The main component of chromosomes is DNA The chromosomes carry genetic information besides directing the chemical activities of the cell The genetic information is carried by segments of DNA called genes (a sequence of nucleotides)

Chapter XII

# CELL DIVISION

In all living organisms, each cell grows and produces other cells. As the cells of the body are constantly wearing out and leaving the body in the form of excretions, it is essential that the materials lost are replaced and new cells are produced. In a mixed population the cells in the process of division are usually large ones. To explain this relationship between the sizo of the cell and onset of division, specific criteria such as the nucleo-cytoplasmic ratio or critical mass have been emphasized. But a more intensive examination of the data makes the hypothesis of causal relationship between cell division and size untenable; for example, the synchronous divisions of the fertilized egg of sea-urchin is not accompanied by periods of growth.

Cells usually divide by indirect cell division, also called Mitosis. In lower organisms, this is the type of division by which the population grows. But in multicellular organisms, division is linked with differentiation.

The reproduction of cells consists of the doubling of all the components of the cells, followed by a division distributing the components equally to the daughter cells. This distribution of materials takes place either by partition of the free organelles or by some other precise mechanism. The whole reproductive cycle is controlled by the nuclear genes.

*Cell life cycle:* The cell passes through the following stages:

1. *Interphase:*

(*a*) G–1 period of growth consists of that period between the completion of cell division and the beginning of DNA synthesis. Generally the longest and most variable in duration. Active RNA and protein synthesis may occur.

(*b*) *S–period*: this is the period of replication of genetic material, or DNA synthesis.

(*c*) *G2*– It is the period of preparation for division. It is a lag period generally observed between the completion of DNA synthesis and the onset of the first recognizable signs of mitosis. RNA and protein synthesis may occur.

2. *Mitotic phase*: represents the actual division of the cell. It is the shortest period in the life cycle of the cell.

## A. INTERPHASE

The combined *G1*, *S* and *G2* phases are called the interphase. During this period, preparations for mitosis are made and the bulk of the synthetic requirements are fulfilled. The events that occur in interphase may be listed as follows:

**1. DNA Duplication.** This is one of the most important event in interphase by which the DNA content of the nucleus is doubled. From experiments done in the test-tube, it is now known how DNA synthesis may take place in the cell. The double stranded nature of the DNA, wound in the form of a helix has induced scientists to suggest possible ways in which the double stranded DNA could synthesise another DNA double strand, of which each strand would be an exact copy of the original. Taylor, Levinthal, Meselson and Sahl and others have contributed much to our knowledge in this respect. DNA replication however is not a requisite to cell division but cell divisions do not take place without a previous duplication of the DNA content.

### Replication of DNA

Many models have been proposed to explain the possible ways in which DNA may replicate.

(*a*) *Conservative type:* According to this model, the original molecule of DNA retains its structural integrity throughout the cell division and the parental DNA helix would be passed on to the progeny in intact form and one of the daughter cells get the newly replicated DNA molecules.

(*b*) *Dispersive type.* According to this model, there is extensive breakdown of the original DNA and it is distributed uniformly among the daughter cells.

(c) *Semiconservative mechanism:* According to this model the parental DNA molecules retain their chemical identity but not their physical identity. The two polynucleotide strands unwind and separate but there is no chemical breakdown of DNA. The two strands will divide between the two daughter cells. This type of replication is substantiated by labelling experiments and seem valid.

2. **Reproduction of Centrioles:** This is another pre-requisite to division. The centriole seems to reproduce by the outgrowth of the daughter centriole by the parent particle and the new particle invariably grows at a right angle to the parent.

3. Increase in the mass of the cell, nucleus and nucleolus.

4. Energy liberation for mitosis.

5. Increase in s**Sulphahydryl compounds.**

6. Macromolecular synthesis for the spindle formation.

7. All these events overlap to maintain a fludity in cellular events.

## B. MITOTIC PHASE

The sequence of mitotic events are divided into four stages for convenience though it is really a continuous process and the phases run into the succeeding phase.

### 1. Prophase

This is the period of preparation.

(a) This is the stage when there is morphological evidence of the biochemical event of DNA duplication and the exact number and size of the chromosomes becomes apparent. The tangle of threads are packed into compact masses that can be moved freely and without getting entangled. This is done by coiling and super-imposed coiling of the chromatin threads. The inner mechanisms of the coiling in large scale is not very clear. The chromosomes become surrounded by a matrix. The chromosome itself is composed of two strands called chromatids which lie close together and it is not always possible to see the split in the chromosomes throughout its length. The chromatids may be coiled about each other. If the semi conservative model of DNA replication is accepted, the chromatid coil will contain a new DNA strand and an old DNA

strand. Experiments performed by Taylor with radioactive labels suggest that the strands of chromosome (chromatids) act as a template for the production of another part. It is not known however how many strands of DNA make a chromatid or how this DNA is arranged in the chromosome. Thus while we know something of the DNA duplication at the molecular level, we are not sure of the corresponding structure in the chromosome. The end result however is that a new chromosome is formed which is an exact copy of the one in the mother cell.

It has been noted that upto the time of coiling of chromosome the cell can be prevented from undergoing division by depriving the cell of oxygen or by poisoning its oxidative **enzymes** with carbon monoxide. But after a certain point—about the time the chromosomes are coiling up—it is not possible to stop the division by blocking oxidations.

(*b*) *Disintegration of nuclear envelope.* By this, the barrier between the chromosomes and poles is removed.

(*c*) Nucleolus gradually becomes smaller and eventually disappears.

(*d*) *Assembly of mitotic apparatus* Between the poles and around the nucleus, a mass of material gathers which later becomes the mitotic apparatus. Centrioles move apart and establish poles towards which the chromosomes will move. The poles are pushed apart by the growth of fibres that continue to connect the poles together. They are called the central spindle.

(*e*) The RNA content of the chromosomes increases as well as their phospholipid content.

Thus in prophase, which is long drawn out, the chromosomes are consolidated, poles established and substance of mitotic apparatus is gathered and the cell is now set to divide.

## 2. Metaphase

The centromere or kinetochore which is the anchor point on the chromosome and which has a constant position on each chromosome giving it a particular shape, becomes clearly visible. The spindle fibres are attached to the centromeres of the chromosomes and direct the movement of the chromosomes. The movement of the chromosomes proceeds in two steps. The first step occurs in metaphase. The paired sister chromatids

move into equatorial plane as defined by the poles. At this stage the chromosomes lie in the spindle which is a body between the poles consisting of fibres that connect pole to pole and pole to chromsomes and an unindentified matrix. Asters may be observed to radiate from the pole in the animal cells.

### 3. Anaphase

The second step in the chromosomal movement is seen in this stage. The centromere divides and the chromatids split apart and move to the poles. The separation of sister chromosomes and their migration toward the poles have been described in detail and have also been measured, by microscopic studies as well as by motionpicture camera. The distances travelled by the chromosomes

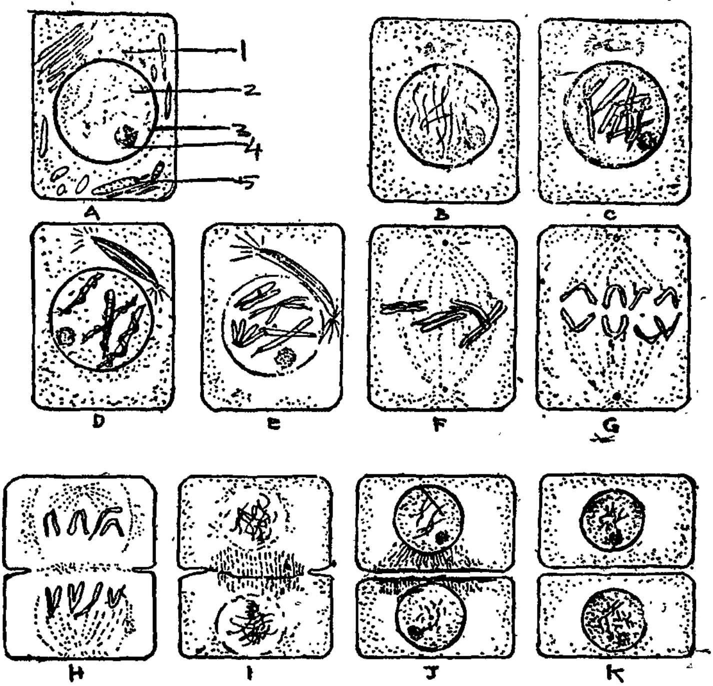



Fig. 59 Mitosis

1. Centrosome 2. Chromonemata 3. Nuclear membrane 4. Nucleolus 5. Mitochondria

is 5 to 25 microns. Velocity is about 1 micron per minute. The chromosomes move in straight lines usually converging at the poles. Often as the chromosomes move towards the poles, the poles are further separated from the other. It is not known with certainty how the movement of the centromeres is controlled nor how each centromere is attached to the spindle fibre.

The mitotic spindle plays a crucial role in this stage. It has been described as a gel, transparent and excludes large particles such as mitochondria. The molecular components of the spindle tend to be orientated along the pole to pole axis. The fibres are fine and straight, usually double and sometimes occur in bundles, running from centromeres to poles. These filaments shorten as the chromosomes move to the poles and lengthen when the poles move apart. Studies from isolated mitotic apparatus give a clue as to their molecular structure. It is chemically unstable when removed from the cell. Therefore it seems reasonable to suspect that there is a stabilizing factor in the internal environment of the cell. Sulphur bonds play an important role in holding the mitotic apparatus together and a compound incorporating sulphur to sulphur bonds seem to be involved. It has been shown that the mitotic apparatus contains a great deal of protein. It also contains RNA much of which is associated with a major protein. There is also considerable amount of lipids. According to earlier experiments, chemical bonds between sulphur atoms on neighbouring protein molecules were considered important for holding mitotic apparatus together.

**4. Telophase**

Once the chromosomes have been separated into two groups, they get organised into two interphase nuclei. They become surrounded by nuclear envelopes. Very little is known of the details of this construction. Nucleolus is reformed.

Now cytokinesis or division of the cytoplasm takes place. This is one of the remarkable events. Many theories have been proposed to explain the mechanism of cytoplasmic division. Division does not depend on the chromosomes but on the mitotic apparatus. In plant cells cytokinesis involves the laying down of a cell plate between the two reorganizing telophase nuclei. In animal cells cytokinesis consists of an equatorial constriction which leads directly to the separation, if the pressure of neighbouring cell is absent.

**Initiation of mitosis**

There are many possible factors which trigger the mitotis, such as doubling in the mass of the cell,upset in the surface to volume of the cell, doubling of DNA content. activity of the nucleolus etc.

## MEIOSIS

Meiosis is the type of cell division which exclusively occurs in the gonads during gamete formation. The factors which initiate meiosis are not fully known. The relative amount of RNA and DNA is one of the possible factors.

The essential characters of meiosis are

1. Pairing and chiasma formation in the chromosomes.
2. Reduction in the number of the chromosomes.

The events of the meiosis occur in two stages, called **Meiosis** I and II. Autoradiographic evidence has clearly demonstrated the completion of DNA synthesis during the meiotic interphase. It has also been demonstrated that the duplication is by semi-conservative mechanism like in mitosis. Almost all the RNA synthesised is of chromosomal origin, very little by nucleoli. In the mitotic nucleus on the other hand the bulk of the RNA is synthesized by the nucleolus. In addition the RNA is synthesized during the later stages of meiotic prophase when nucleolus is not present. Ribonucleic proteins may also be synthesized during the different stages of prophase in meiosis, the most active periods being leptonema and pachynema.

**Meiosis I**

**1. Prophase I**

It is of extremely long duration during which there is an increase in nuclear volume by gradual modification in nuclear structures. It is subdivided into 5 substages.

(*a*) *Leptonema* (*Leptotene*): The chromosomes are long and are greatly extended and uncoiled. They show maximum extension. In late leptonema, the chromonema are of uniform diameter thrown into large number of coils of small size. Duplication of chromosomes may occur in this stage in some cells. In

many animal cells, the free ends of the chromosomes are attracted to the side of the nucleus nearest the centrosome and the body of the chromosomes extends in a loop in the interior. The chromosomes then present a bouquet like appearance. The chromosomes are said to be polarized. The nucleolus increases in size, in volume and RNA content between leptonema and the next stage zygonema. At the end of leptotene, chromosomes are shorter in length and wide in diameter due to increase in the diameter of the spirals.

(*b*) *Zygonema:* It is one of the most important stages of prophase I. Two similar chromosomes (the homologous chromosomes) one from the paternal and the other from the maternal origin, are brought into apposition at one or several places (synapsis). After the first contact, pairing continues in a zipper like fashion along the chromosomes. The pairs so formed are called bivalents. Since each chromosome is formed of two chromatids, each bivalent consists of 4 chromatids or tetrads. The reason for pairing is not clearly understood. This stage is of long duration.

(*c*) *Pachynema:* The pairing is completed and the number of pairs of chromosomes is now half the diploid number. The chromosomes become shorter and thicker about 1/4th or 1/6th of leptonema. Sometimes the apposed homologues are twisted about one another. Crossing over occurs at this stage and bivalents exchange their segments by chromosomal break and union resulting in cross shaped figures called chiasma. The number of chiasma depends on the length of the chromosome and the time of occurrence is variable. The localisation of chiasma seems to be under genetic control.

(*d*) *Diplonema:* This stage is characterised by the tendency for paired chromosomes to fall apart. The repulsion between centromeres is very evident and the chromosomes are attached only at the chiasma. As a result, the bivalents appear as loops. In the late diplotene, terminalization occurs by which chiasmata move towards the chromosome ends.

(*e*) *Diakinesis:* The chromosomes become still shorter due to further coiling and individual chromatids cannot be identified. Terminalization is completed (if not already completed) and the bivalents migrate to the periphery of the nucleus where they lie

in close association with the nuclear membrane and widely separated from one another. The last remnant of the nucleolus disappears. Nuclear membrane breaks down and the spindle is formed by the centrioles.

**2. Metaphase I**

The bivalents are now established on the spindle. The two homologous centromeres of each bivalent lie towards the poles while the arms of chromatids are directed towards the equator. The spindle fibres which are connected to the centromeres are called chromosomal fibres.

**3. Anphase I**

The tetrads become separated into two dyads. The chiasma slips off at the free ends, thus disengaging paired homologues. A dyad consists of two chromatids each made up of two arms, so it appears as a double V or double J. The four arms do not lie closely appressed during anaphase I but diverge as if they were mutually repelling one another.

**4. Telophase I and Interphase**

The chromosomal dyads reach their respective poles. Nuclear membrane is formed and chromosomes elongate, loosening the coils. But they do not fully extend as the interphase is short. There is no duplication of the chromosomes and dyad reappears unchanged in prophase II.

**5. Prophase II**

It is unspectacular and there are no unusual phenomena. Superficially, it resembles ordinary somatic division. The two chromatids look like 'x', connected by centromeric regions with arms widely apart. There is no relational coiling, but the chromonemata are not completely uncoiled. The genetic constitution of the two chromatids of each dyad depends on the kind of and members of cross over. Nuclear membrane and nucleolus begin to disappear.

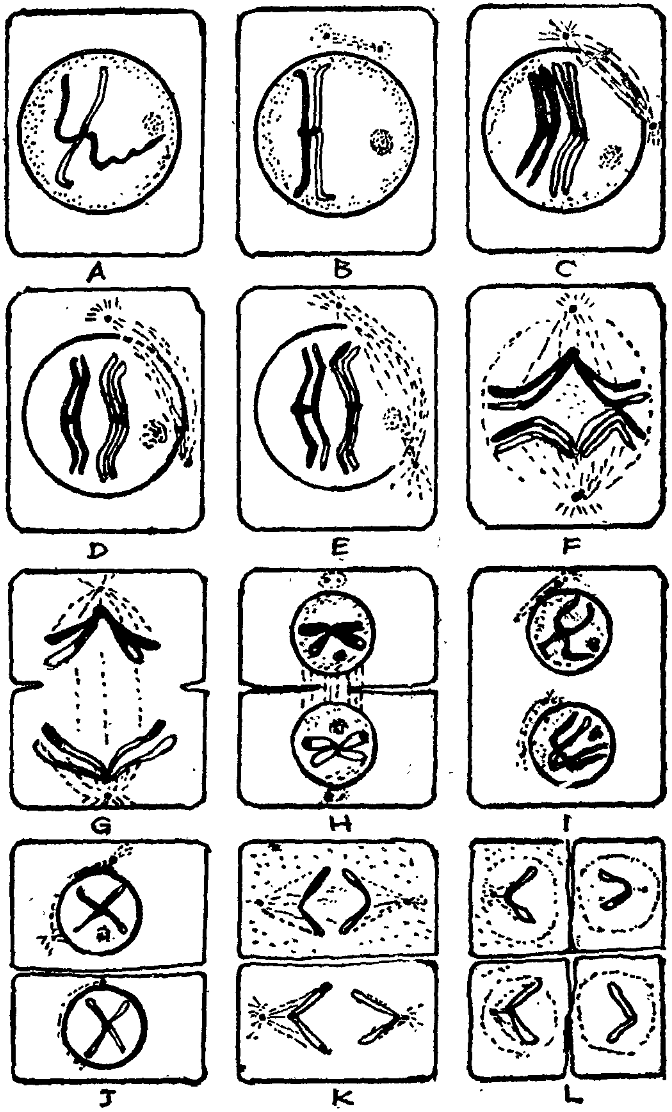



Fig. 60 *Meiosis*—Stages

**6. Metaphase II**

This stage is of very short duration. The chromtids become lined up with the centromeres on the equator. The centromeres lie along the equator while their arms are separated out Centromere becomes functionally double.

**7. Anaphase II**

The chromosomal fibres arise from the centrioles and the two chromatids move to opposite poles.

**8. Telphase II**

The daughter chromosomes formed of the chromatids uncoil and nuclear membrane and nucleolus appear.

Cytokinesis follows, each with reduction in the chromosome number and recombination achieved.

**Comparison between Mitosis and Meiosis**

| | *Mitosis* | *Meiosis* |
|---|---|---|
| 1. | This cell division is called indirect division. | This is called reduction division. |
| 2. | This takes place in all growing parts of plants like, shoot tips, root tips etc, and in the body cells of animals. | This takes place only in the reproductive organs, during gametogenesis. |
| 3. | As a result of Mitosis, two daughter cells, which are idential quantitatively and qualitatively are created. | As a result of Meiosis, four cells each different from the other in chromatid content, and all having only half the number of chromosomes as the mother cell are formed. |
| 4. | Prophase of Mitosis is of short duration. | Prophase is a prolonged affair, (i.e.) takes a longer time. |
| 5. | There are no substages in prophase. | There are 5 substages in prophase, namely leptotene, zygotene, pachytene, diplotene and diakinesis. |

| | *Mitosis* | *Meiosis* |
|---|---|---|
| 6. | Chromosomes do not pair during prophase. | Homologous chromosomes pair during zygotene. |
| 7. | There is no exchange of genetic matter between chromosomes. | There is an exchange of segments of chromatids between homologus chromosomes. |
| 8. | Chromosomes split up into two chromatids, completely. The separation starts with the splitting of centromeres during Metaphase. | Chromosomes do not split entirely. The centromeres do not divide. |
| 9. | During Anaphase, Chromatids are separated and pulled towards opposite poles. | Chromosome pairs are separated during Anaphase Chromatids are not separated. |
| 10. | Only two daughter cells are formed at the end of Mitosis. | Four cells are formed because there is a second division called Meiosis II. |

## Chapter XIII

# DIFFERENCE BETWEEN ANIMAL AND PLANT CELLS

1. In most plant cells, the cell wall is a semi-rigid, laminated, external, covering. It is secreted by the cell and gives protection and support, covering the living plasma membrane beneath. In some plants, it contains minute pits or canal like plasmodesmata, that connect adjacent cells. In plant cells it is made primarily of cellulose. Other compounds such as fatty substance, tannins proteins, gums and mucilages also may be present in the cell walls. The cell walls provide tensile strength and protection to the cell and to the plant as a whole. It counteracts the osmotic pressure being developed by the cell inclusions. They also serve to provide sites for enzymatic activity and a passage for materials for growth of the cells. The cell wall also serves as a barrier preventing the penetration of several microorganisms into the cytoplasm.

2. Cytoplasmic vacuoles are fewer and larger in plants. They may function for storage, for transmission of materials and for help in maintaining the internal pressure in cells.

3. Plastids are organized bodies, usually spherical oval or ribbon shaped, and are present in certain plant cells. These types found in plant cells include (*a*) chloroplasts which contain green chlorophyll and absorb radiant energy to photosynthesize foods (*b*) chromoplasts, which are usually yellow, orange or red and occur in flowers and fruits (*c*) leucoplasts which are colourless and may store energy rich starch as in the potato tuber. Rhodoplasts are red coloured plastids found in Rhodophyta and Phaeoplasts which are yellow plastids found in brown algae, diatoms and dinoflagellates.

4. Centrioles are not found in higher plants, though it may be present in certain lower plants such as brown algae.

## Chapter XIV

# D.N.A. AND R.N.A.

## (Basic Organisation of these Macromolecules)

Every cell contains a Nucleus. The Nucleus has inside it a network of thread like structures called the chromatin reticulum. This network condenses and organises itself as individual chromosomes during the cell division. These undergo a duplicating process during every mitotic division so that the new daughter cells have the same component of chromatin material, both quantitatively and qualitatively. The chromosomes are known to be the seats of genes or the factors that govern the heredity. Besides it is the chromosome that governs all the chemical activities of the cell. Each chromosome has a definite number of genes in a particular sequence. Such an important item in the cell needs to be understood well, if we are to comprehend the wonders of the living world. The number and shape of chromosomes for any given species of living organism is constant. For example the human body cells have 46 chromosomes.

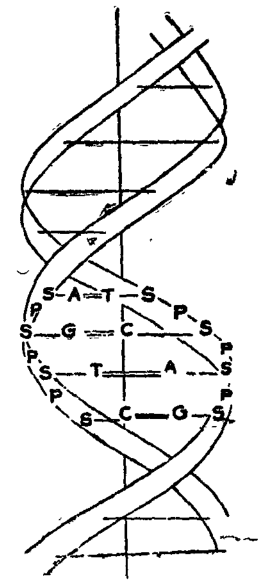



Fig. 61 D.N.A. structure

Chemical analysis of the chromosomes show that they are made of a nucleic acid known as D.N.A. or Deoxyribose Nucleic Acid. What is D.N.A.? It is a macromolecule of certain chemical principles. Each molecule of the D.N.A. consists of sugars, phosphates, and 4 types of nitrogenous bases. The sugars are deoxyribose sugars. The sugar is a pentose sugar (5 carbon sugar). The position of the elements are best seen in the diagram below:

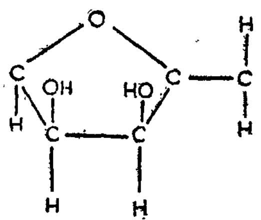



Fig. 61 (a)

The phosphates are the connecting links between the sugars. The phosphate is represented by

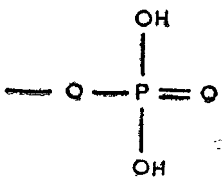



Fig 61 (b)

The 4 types of nitrogenous bases are Adenine, Guanine Thymine and Cytosine. The adenine and guanine are known as Purines. The thymine and cytosine are called Pyrimidines. These nitrogenous bases are usually attached to the sugars in the Nucleic Acid The chemical nature of these nitrogenous bases are shown below:

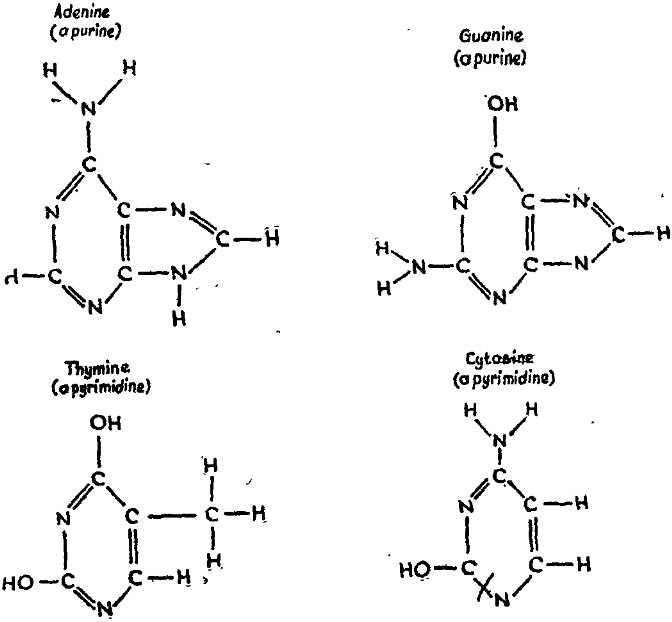



Fig. 61 (c)

The D.N.A. molecule is a macromolecule having a molecular weight ranging between 30,000 to several millions. The nature of the molecule was first demonstrated by a model conceived by two scientists by name J. H. Watson and F. H. C. Crick (Nobel Prize Winners). They believed that the D.N.A. molecule is like a twisted ladder The two rails of the ladder are formed by the sugar and phosphates arranged in a linear fashion alternately. The sugars in the two rails of the ladder a. just opposite and they are connected across by a rung of the ladder. The rung is formed by the nitrogenous bases. As a rule, a purine and a pyrimidine join together to form a rung. Not only that, but it is always the purine Adenine and the pyrimidine Thymine that form a rung. Similarly the purine Guanine joins a pyrimidine Cytosine to form a rung These rungs connect the sugars of the two rails of the ladder. The connection between a purine and a pyrimidine is formed by what are known as hydrogen bonds. The adenine thymine rungs are connected by 2 hydrogen bonds and the guanine cytosine rungs by 3 hydrogen bonds. So the guanine cytosine links are a little more stronger. The sequence of the nitrogenous bases

forming the rungs can be modified into innumerable ways and that accounts for the millions of different D.N.A. molecules forming variety of organisms.

The twisted ladder like D.N.A. molecule is referred to as a double helix. The width of the helix is about 20A° (1A° Angstrom is $\frac{1}{10000}$ of a micron : 1 micron is $\frac{1}{1000}$ of a mm). One twist of the helix has about 10 rungs across and has a length of about 34A°.

The unit of one sugar and one nitrogenous base, together is known as a nulceoside. There are therefore 4 types of nucleosides in the D N A, equal to the combination of the sugar with the 4 types of the nitrogenous bases. Each nucleoside along with a phosphate comes to be called a nucleotide. An average D.N.A. molecule has thousands of nucleotides. A gene is a sequence of nucleotides the minimum number of them being three. While the D.N.A. is found in the Nucleus, the other Nucleic Acid namely R.N.A. is found both inside the nucleus and outside in the cytoplasm.

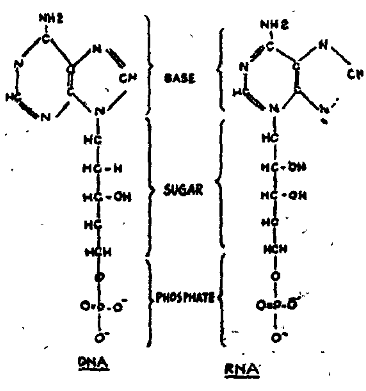



Fig 62 D.N.A. and R.N.A.

R.N.A. is Ribose nucleic acid. The sugar in this molecule is Ribose sugar, while in the D.N.A. it is deoxyribose sugar (i.e. minus –OH). Besides there is no Thymine in R.N.A. It is

replaced by another nitrogenous base called Uracil. The uracil is represented as below:

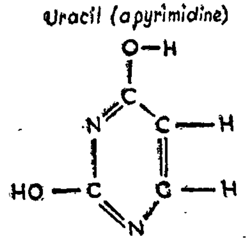



Fig 62 (a)

The R.N.A. molecule is not like a double helix but like a loop.

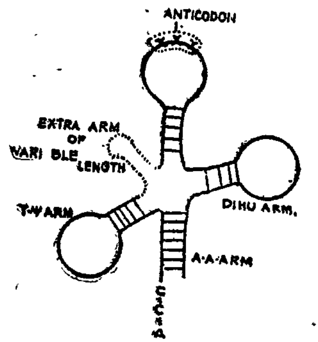



Fig. 63 R.N.A. structure

The R.N.A. molecule is mainly of 3 types. They are—(1) Transfer or soluble R.N.A., (2) Template R.N.A. or messenger R.N.A., and (3) Ribosomal R.N.A.

The R.N.A. plays an important role in protein synthesis (refer Chapter on Protein Synthesis).

## Chapter XV

## TISSUES

A Tissue is a group of cells, which are all, similarly modified, in order to carry out a particular function. Though an organism is made of numerous cells, all the cells are not similar. Cells undergo structural changes in order to suit the special function performed by them. This kind of structural modification to suit the functional needs is a consequence of division of labour and it is called differentiation. Such a group or assembly of similarly modified cells with a common function is called a tissue (e.g. Epithelium, Muscle, Nerve, Connective tissue, Cartilage, Bone, Blood and Germ cells).

**Epithelium:** This is usually a protective tissue. It is formed by a layer of cells above which, there is a free surface. The free surface may be external or internal. The cells are all arranged in a single layer on a gelatinous substance called matrix or basement membrane. Blood capillaries and nerves stop in the matrix. So the cells of the epithelium have to take whatever they want only from the Matrix. The epithelia are of different types:

1. *Columnar epithelium:* This type of epithelium is found on the inner wall of the oesophagus, intestine and in some ducts. The cells of this epithelium are long and pillar like. Their inner ends are narrow. They are arranged vertically on the Matrix. This epithelium helps in absorption.

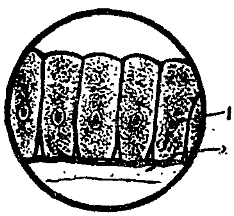



**Fig 64** Columnar epithelium.
1. Nucleus 2. Matrix

2. *Ciliated epithelium:* This type is found on the inner wall of the trachea in Man. The cells of this epithelium have minute hair like cilia on their free outer surface. The cilia exhibit vibratile movements. The cilia help to move particles on the surface gently. In other words, they help to keep the surface clean.

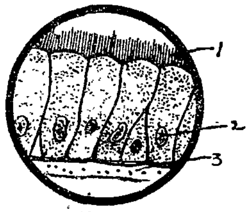



**Fig. 65** Ciliated epithelium

1. Cilia 2. Nucleus 3. Matrix

3. *Glandular epithelium:* This type is found on the inner wall of the stomach and in many glands. The cells of this epithelium are capable of secreting fluids like mucus or enzymes. Some of the cells are having cavities, resembling wine glasses. These are called goblet cells. The glands may be on the surface, or invaginated like a test tube, or it may be a very much branched gland.

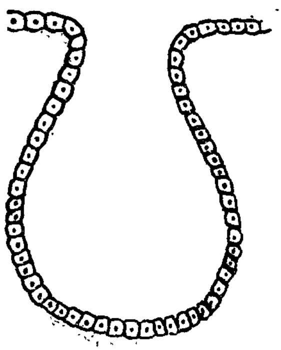


Fig. **66** Glandular Epithelium

4. *Squamous epithelium:* This is found on the inner wall of the lips. The cells are reduced to thin plate like or scale like structures. The cells are arranged on the matrix like the stones

or tiles on a pavement. So it is also called a pavement epithelium. The main purpose is protection to the tissues below.

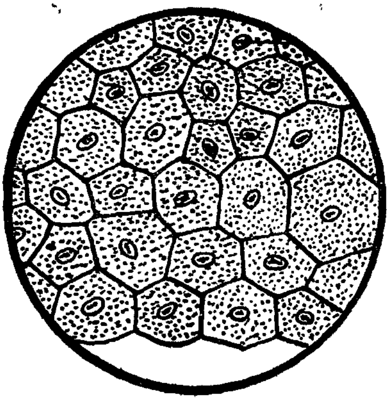


**Fig. 67** Squamous Epithelium

5. *Stratified squamous epithelium:* This is found in the corneous layer of the epidermis of the skin. The cells are also dead and reduced to thin plate like scales. But there are several layers of these cells on the matrix.

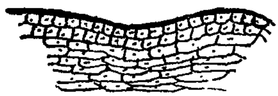


**Fig. 68** Stratified squamous epithelium

6. *Germinal epithelium:* On the inner wall of the gonads (testis or ovary) epithelial cells give rise to reproductive cells. So it is called germinal epithelium.

7. *Sensory epithelium:* The sense organs like skin, tongue, nostrils etc., have a layer of sensitive cells which convey impulses to the brain and help it to understand the various senses. So these cells form the sensory epithelia.

**Muscle Tissue:** The muscle cells are adapted for bringing about movements. The cells are long and contractile. They can contract and relax. This is a physico-chemical reaction. It is **also a reversible reaction.** The muscles are of 3 types.

1. *Voluntary muscles:* The muscle cells are long and cylindrical. The nucleus is placed towards one side of the cell. The cell is enclosed in a protective sheath called Sarcolemma. The muscle cell shows many dark and light bands across its length These are known as striations or stripes. Hence these muscles are also called striated or striped muscles. The muscle cells are found in bundles called fasciculi. Many fasciculi are bound into a muscle. These muscles are usually found attached to the bones of the skeleton. So they are called skeletal muscles. These muscles work under the control of conscious will. Hence the name voluntary muscle (e.g. Biceps, Triceps etc.).

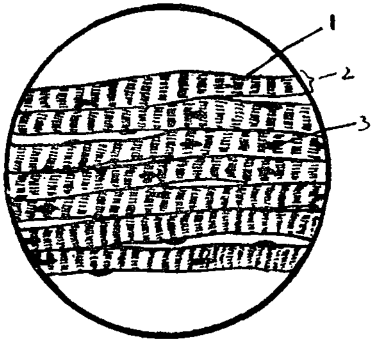



Fig. 69 Voluntary muscle
1. Striations. 2. Muscle fibre 3. Nucleus

2. *Involuntary muscle* or *smooth muscle:* These muscle cells are spindle shaped, with a middle broad portion and tapering ends.

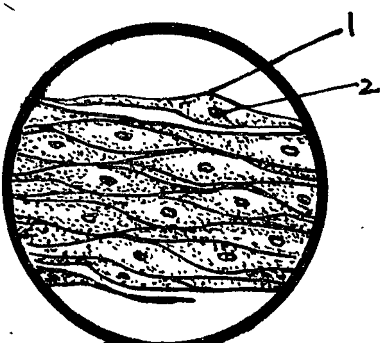



Fig. 70 Involuntary muscle
1 Cell 2. Nucleus

The nucleus is in the centre. There are no stripes or striations. There is no sarcolemma. The muscle is called unstriped or non-striated muscle. These muscles are not under the control of will. So these are called involuntary muscles (e.g.) muscles on the wall of the alimentary canal, urinary bladder etc.

3. *Cardiac muscle:* The wall of the heart is made of a special type of muscle cells. The cells are branched and connected like a network. In each cell, the nucleus is towards one side and there are dark and light bands across the cell. In these respects it is like voluntary muscles. There is no sarcolemma and these muscles are not under the control of the will. Hence it is like involuntary muscle. But the heart muscle cells are different from both voluntary and involuntary muscles in being branched.

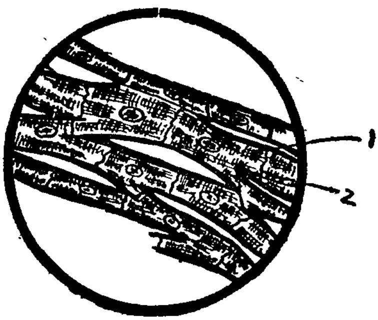



**Fig. 71** Cardiac Muscle

1. Cell 2. Branch

**Nerve Cells:** The nerve cells are also called Neurons. These cells are highly modified for communication inside the body of an animal. The cells are extremely adapted and sensitive. The brain, spinal cord and the nerves are all made of this type of cells. The nerve cell has an irregular cytoplasm with a nucleus in the centre. The cytoplasm contains many granules called Nissl's granules (R.N.A.). The corners of the cell are produced into small tree like branches called dendrites. Nerve messages enter the cell only through the dendrites. From one corner of the cell, arises a long fibre, called Axon fibre. Messages leave the cell through the axon fibre.

This fibre is covered by 2 coats. The inner coat is called Myelin sheath or sheath of Schwann. The outer coat is called Neurilemma. This coat is constricted at intervals. These constrictions

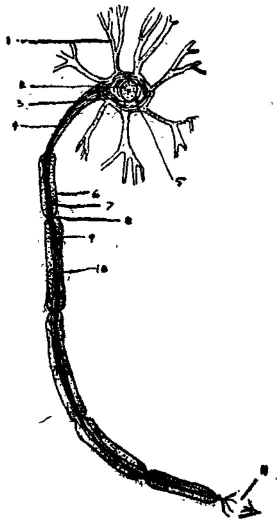


**Fig. 72** - Nerve cell

1. Dendrites 2. Nucleus 3. Cytoplasm 4. Axon fibre 5. Nissl's granule 6. Neurilemma 7. Myelin sheath 8. Node of Ranvier 9. Nucleus 10. Axon fibre 11. Synapse

are called nodes of Ranvier. The free end of the axon fibre is branched and it always joins the dendrite of another neuron. At the junction, a small gap called synapse is present. In this gap, messages are transmitted chemically.

A nerve is a bundle of axon fibres. The nerve cells or neurons are present only in the brain, spinal cord and in the ganglia.

**Connective Tissue:** The many tissues in an organ are kept in position and bound together by the connective tissue. This tissue has few large cells which secrete a gelatinous matrix. The matrix is strengthened by bundles of unbranched white fibres and single branched yellow fibres. These fibres are produced by

special cells called fibrocytes. The fibres are made of a material called collagen.

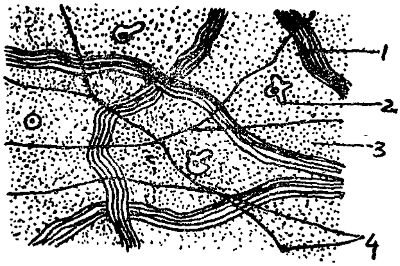



Fig. 73 Connective tissue

1. White fibres 2. Cell 3. Matrix 4. Yellow fibres

**Cartilage:** The Cartilage is found at the junction of two or more bones. The external ear and the tip of the nose are supported by cartilage. The cartilage is a tough, but at the same time flexible tissue. It acts as a cushion at the junction of bones.

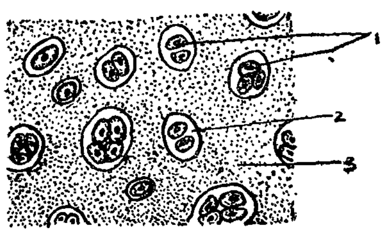



Fig. 74 Cartilage

1. Cartilage cells 2. Lacuna 3. Matrix

The cartilage cells appear in groups of twos and threes. The cells secrete a matrix made of chondrin. Because of the matrix, the cells appear to be inside cavities called lacunae. There are three types of cartilages (1) Hyaline cartilage, when the matrix is free of fibres and salts. (2) Fibrocartilage when the matrix shows fibres running across and (3) Calcified cartilage, when the matrix is full of calcium salts to give it additional strength.

**Bone:** The bone is a hard structure in the centre of which, there is a soft tissue called red marrow of bone. (New red blood corpuscles are produced in the marrow.) The hard part contains many small cavities known as Haversian canals. Each Haversian canal contains a blood capillary. The Haversian canal is surrounded by many small cavities arranged concentrically. These are the lacunae containing the bone cells or osteoblasts. The bone cells are all connected with each other, and with the Haversian canal by minute tubes called canaliculi. The substance in between the canaliculi, is the matrix. It is fully impregnated with calcium salts. Bones give strength, shape and support to the organisms.

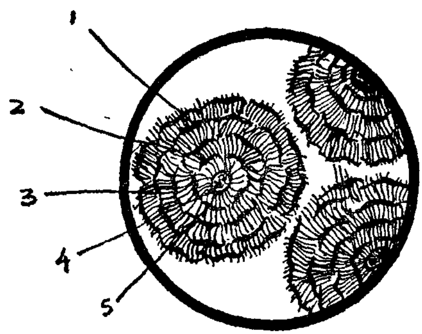



Fig. 75 Bone

1. Bone cell 2. Canaliculi 3. Matrix 4. Haversian canal 5. Capillary

**Blood:** Blood is a tissue made up of a liquid matrix called plasma, in which, groups of cells called corpuscles float. The plasma is a pale yellow watery liquid containing about 95% of water. It also contains digested food (glucose and amino acids) metabolic waste (urea, uric acid) gases ($O_2$ and $CO_2$) hormones (secretions of ductless glands) antibodies, inorganic salts (chlorides, carbonates, sulphates of Calcium, Sodium, Iron, Magnesium, Iodine, Potassium etc.) and blood proteins (serum albumen, serum globulin, prothrombin and fibrinogen) The plasma being a liquid is useful for distribution of food, $O_2$, heat etc.

The corpuscles are of three types namely (1) red corpuscles or erythrocytes (2) white or colourless corpuscles or leucocytes and (3) platelets or thrombocytes. The red corpuscles are more

numerous and are formed in the red marrow of bones. They live for 3 to 4 months and old corpuscles are destroyed in the liver. The corpuscles are biconcave with a thick rim. These contain a red pigment called Haemoglobin, which has an affinity for oxygen. It combines with oxygen to form an unstable compound called oxyhaemoglobin. This gives up the oxygen in the tissues and becomes once again haemoglobin. So it helps respiration by transporting oxygen. The red corpuscles cannot move of their own accord and they usually group themselves as a pile of coins. (The red corpuscles of frog, are nucleated and oval in shape. In Mammalian blood as the human blood, the nucleus is not seen and the cells are circular.)

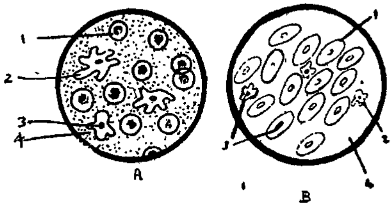


**Fig. 76** A—Human Blood B—Frog's Blood
1. Red corpuscle 2. White corpuscle 3. Nucleus 4. Plasma

The white or colourless corpuscles are of different types. But they are mainly amoeba like with no permanent shape. They are smaller in number and move about with the help of pseudopodia. They devour foreign germs that enter the body and thus protect the body from diseases. So these corpuscles are called phagocytes. White corpuscles are classified into Basophils, Neutrophils, Eosinophils, Monocytes etc.

The platelets or thrombocytes are very small and they help to prevent loss of blood whenever there is an injury, by causing blood clot. The clotting of blood is a chain reaction brought about by an enzyme called Thrombokinase, produced by the platelets.

Platelets ——→ Thrombokinase
↓
**Calcium salts + Prothrombin**
↓
**Fibrinogen + Thrombin**
↓
**Fibrin threads + corpuscles = Clot.**

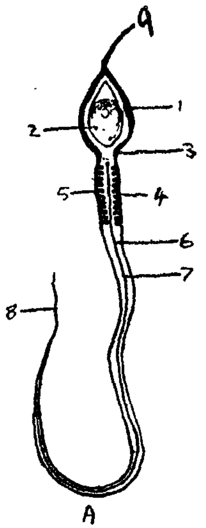
*Functions of Blood :*

1. Blood distributes the digested food.
2. Blood carries oxygen from the respiratory organs to all tissues.
3. Blood removes $CO_2$ from the tissues to the respiratory organs.
4. Blood takes the metabolic waste products to the excretory organs.
5. Blood provides all the raw materials required by the glands in the body.
6. Blood carries the hormones, which are the secretions of endocrine glands.
7. Blood distributes the heat evenly throughout the body.
8. Blood gives tissue pressure to the cells to counteract atmospheric pressure.
9. Blood keeps all the tissues moist and supple.
10. Blood prevents its own loss by clotting at the place of injury.
11. Blood protects the body from disease causing germs.
12. Blood carries antibodies to counteract toxins or poisons.

**Germ Cells:** The reproductive organ of an animal is called a gonad. The male gonad called the testis, produces the male gametes or sperms. The female gonad, called the ovary, produces the female gametes or ova or egg cells.

The gametes are produced as a result of reduction division or Meiosis. The production of gametes is known as gametogenesis. The gametes will have only half the number of chromosomes as the body cells i.e. they will be haploid. During fertilisation, 2 gametes i.e. haploid cells, meet and fuse to form a diploid cell or zygote.

The formation of male cells or sperms is called spermatogenesis. The sperm is very small. It has a head, a neck, a middle piece and a tail.



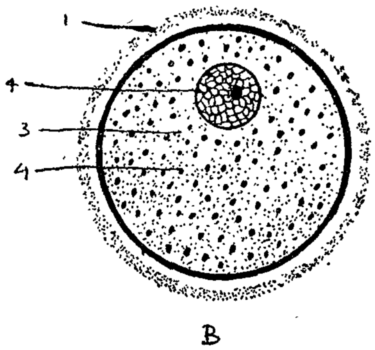




Fig. 77 A-B. Germ cells

A—Sperm

1. Head 2. Nucleus 3. Neck 4. Middle piece 5. Mitochondria. 6, 7, 8. Tail 9 Acrosome.

B—Ovum

1. Vitelline membrane 2. Nucleus 3. Cytoplasm 4. Yolk granules

The head contains the nucleus, which occupies almost the entire head. There is a little cytoplasm at the tip, called the acrosome. The neck contains a centriole. The middle piece contains a few mitochondria, which provide energy. The tail is long and is useful in swimming towards the female cell.

The ovum or egg cell is produced by oogenesis. The egg cell is comparatively very big and it is usually spherical. The nucleus is not exactly at the centre. The end of the cell, towards which nucleus is seen, is called the animal pole. The opposite end is called the vegetal pole. The cytoplasm of the egg cell is full of nutritive matter called the yolk. It appears as yolk granules. (The amount of yolk may be little or may be heavy according to the nature of the egg.) The egg cell is enclosed inside a membrane called vitelline membrane.

Many sperms surround an egg cell, but only one succeeds in entering it. As soon as the head of the sperm enters, the rest of the sperm is cut off. The egg cell develops a fertilisation membrane to prevent other sperms from entering.

The fertilised egg cell is now called a Zygote. This divides repeatedly and rapidly to form numerous cells, which arrange themselves to become the young one.

Chapter XVI

# CYTOLOGICAL TOOLS AND TECHNIQUES MICROSCOPY

The study of cytology in modern times involves the application of various tools and techniques because the cell is a highly complex unit with different chemical, physicochemical and morphological aspects. The apparatus (tool) that has made possible the study of cells, which are normally invisible to the normal eye is called the Microscope. Particles that can be seen under the microscope are called microscopic particles:

Several microscopes are known today They are:

1. Light Microscope
2. Compound Microscope
3. Phase contrast Microscope
4. Interference Microscope
5. Polarizing Microscope
6. Flourescent Microscope
7. Dark field Microscope
8. U.V. (ultra violet Microscope)
9. Electron Microscope.

Several other techniques like birefringence, Dichorism, X-ray diffraction etc. are now used to describe the ultrastructure of cells.

## Principles in Microscopy

There are two main aims or principles in Microscope. They are:

1. The formation of a magnified (enlarged) image free from optical defects.
2. The achievement of contrast i.e. a difference in the intensity or colour between the object and the background.

A magnified image may be produced by increasing the resolving power of the lens. The resolving power may be defined as the property of an optical system to distinguish objects lying very close together. For example, in observing a double star, some individuals will be able to see only a single star, while others with better resolving power will be able to see two separate stars.

The resolving power may be calculated by considering an image formation in a convex lens. Consider a source of light P in front of a lens AB. Only a very small portion of the light will pass through the centre of the lens, which will pass through it in a straight line. The light rays that pass through the thinner edge of the glass, bend and are brought to a focus at $P^1$.

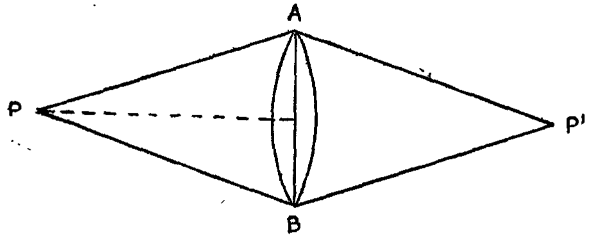



**Fig. 78**

Now resolving power is given by the formula $r = k\lambda/NA$ where $k$ is a constant and is equal to $k = 0.61$. Thus resolving power $r = \dfrac{0.60 \times \lambda}{NA}$ where $NA$ is the Numerical Aperture.

If the $\angle APB$ is $2\mu$ then the $NA = n \sin \mu$ where $n$ is the refractive index of the medium. In this way the maximum resolution of visible white light has been found to be 0.25 microns (1 micron $= 0.001$ mm).

## 1. Light Microscope

The light microscope is the most simplest of all microscopes. It consists of chiefly:

1. The objective lens which lies close to the object, and which has a high resolving power.

2. *Ocular or eyepiece* which lies nearer the observer (viewer) and which merely magnifies the object resolved by the objective.

The next most important part is a *light source* (usually sunlight) which is made to pass through the object by means of a *movable mirror adjustment*, which is a plano concave mirror. There is also a *mounted circular disc* on which the object can be placed and observed.

By means of the light Microscope one can only see in a magnified form the external morphology of minute organisms or cells.

## 2. Compound Microscope

The essential parts of a compound microscope consist of (1) a light source (2) a condensing lens system to collect and enlarge further the image formed by the objective.

This consists of a body tube. At one end (lower end) is fitted the objective while the ocular or eyepiece is seen at the upper end. In this microscope the magnification occurs in two stages. First an inverted and magnified image of the object is formed by the objective, and secondly this image is further magnified by the ocular or eyepiece. The maximum power of resolution of a good compound microscope is about 1500 times.

There are as many as three objectives of different magnifying powers attached to a revolving nose piece. A pair of focussing knobs fo. coarse and fine adjustment is present to facilitate the adjustment of the body tube for sharp focussing of the image. There is a mechanical stage attached to the general framework of the microscope, intended for holding a glass slide on which the specimen to be studied is placed. The glass slide is kept in place by a pair of clips attached to the stage. The object is illuminated from below by reflected light from a plano concave mirror attached to the main framework, beneath the stage. Between the reflector and the stage is a condenser and an iris diaphragm. The condenser can be raised or lowered by rack and pinion adjustment. This serves to control the intensity of light falling on the object. The entire system is mounted on a solid frame supported by a strong and heavy two pronged base.

A variation of this ordinary compound microscope is the binocular microscope which has two eyepieces permitting the viewer to observe the object with both the eyes.

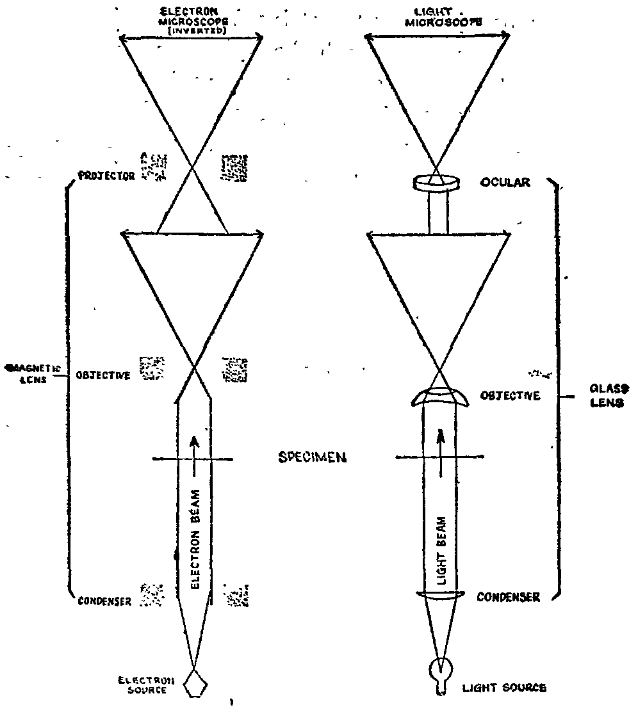



Fig. 78 A. Optical principles

### 3. Electron Microscope

The Electron Microscope was introduced in 1940 and has contributed greatly to our knowledge of the cell structure. It is relevant here to point out some of the differences between the light microscopes ordinarily used and the electron microscope. The electron microscope uses instead of light, a beam of electrons with a wavelength of less than one Angstrom (A°–0.1 m). Instead of glass, it uses electromagnetic fields as lenses and condensers capable of refracting the beam of electrons, in the same manner as the light microscope handles light. Instead of the retina of the eye, the electron microscope produces the mage on a fluorescent screen or a photographic plate. In this microscope, though theoretically the resolving power is less than 1 A° engineering and technical problems are great and so far resolution of 6 to 8 A° has been achieved infrequently. Resolution of 20 to 40 A° is common.

The main drawbacks of the Electron microscope is that specimens must be 'dry' and ultra thin. We therefore see under the microscope only structures that are no longer alive.

During the last few years new cytological techniques have been developed which have also contributed greatly to our understanding of the complex anatomy of the cell. These techniques include (*a*) cytochemical and histochemical techniques by the methods of differential staining and detection of specific substances (*b*) techniques of isolation by homogenization centrifugation and microsurgery (*c*) autoradiography and (*d*) tissue culture methods.

## STAINING TECHNIQUES FOR LIVING AND FIXED CELLS

Vital dyes penetrate living cells and color certain structures without seriously injuring the cells. For example, neutral red may be used to stain the cytoplasm although in some cells it accumulates in vacuoles instead. Janus green B stains mitochondria selectively. Methylene blue selectively stains the Golgi apparatus. Vital dyes are not entirely harmless, but they kill only after cells have been exposed to them for a long time. Sometimes the poisonous constituent (e.g. the heavy metals in Janus green B) may be removed from a vital dye solution making the dye much less toxic than the original sample. While helpful, the vital dye technique has only limited use because many of the cell organelles are not stained by such dyes and, in all cases, scattering of light obscures boundaries of structures. However dyes have been used to demonstrate that some cell organelles such as the mitochondria, Golgi apparatus and vacuoles are real structures present in the living cell.

Most of the early work on the nature of cell organelles was done with fixed and stained preparations. Fixing agents such as formalin alcohol, acids, salts of heavy metals or mixtures of these, precipitate the proteins and render them insoluble. Next, water is removed from the fixed tissues by dehydrating agents, such as alcohol and the tissues are embedded in paraffin and sectioned with a microtome. The sections are affixed to slides and the paraffin is removed with xylol and washed in xylol-alcohol. By washing in decreasing concentrations of alcohol the sections are partially hydrated and the proteinaceous material of the cell is

then differentially stained to distinguish the structures present. Natural dyes (e.g. hematoxylin) or basic aniline dyes (e.g. safranin and basic fuchsin) stain the nucleus selectively and acid dyes (e.g. orange G, eosin and fast green) stain the cytoplasm. The sections are then dehydrated with alcohol. To reduce scattering of light, it is necessary to replace the alcoholic medium with a substance having the same refractive index as that of the protein particles. This is accomplished with a clearing agent, such as xylol, which infiltrates among the protein particles. The preparation is then mounted in balsam, which has a refractive index about equal to that of the cell proteins. As a result, it is possible to look at the cell and see clearly the stained structures which are within.

## Chapter XVII

# A.T.P. AND ITS ROLE IN CELLULAR ACTIVITY

All activities of life require energy. This energy source can be traced ultimately to solar energy. This is trapped by the chlorophyll of the plants and stored as carbohydrates and fats. That is glucose is built up from raw materials like $CO_2$ and water with the help of solar energy. This glucose is polymerised into starches and sugars (carbohydrates) and fats. For getting the energy for life activities glucose is the starting point. A molecule of glucose is oxidised to release about 673 kilo calories of energy. The energy is in the form of high energy bonds between phosphates. The 673 kilo calories of energy is obtained as 38 A.T.P. molecules in the living cells. In other words the A.T.P. molecules are current coins of chemical energy.

What is an A.T.P. molecule? Each A.T.P. molecule has a nitrogenous base called Adenine (refer Chapter on D N A), a ribulose sugar and three phosphate groups. The Adenine and sugar together form Adenosine, which is a nulceoside. The nuclcoside and one phosphate group forms a Nucleotide. The other two phosphate groups are attached to the first phosphate group of the Nucleotide by what are called high energy bonds.

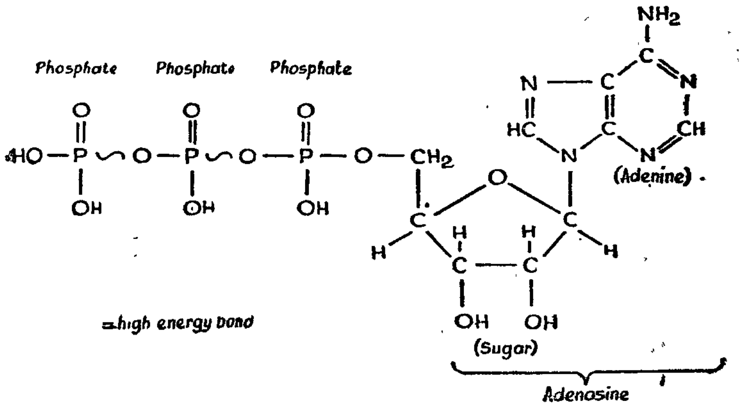



Fig. 79 a

A.T.P is built up during photosynthesis. During the photolysis of water, an electron is released, which is returned to chlorophyll through cytochromes in the cell. During this electron

**Kreb's Cycle**

Glucose ($C_6H_{12}O_6$)

Glucose + Phosphate = Glucose Phosphate

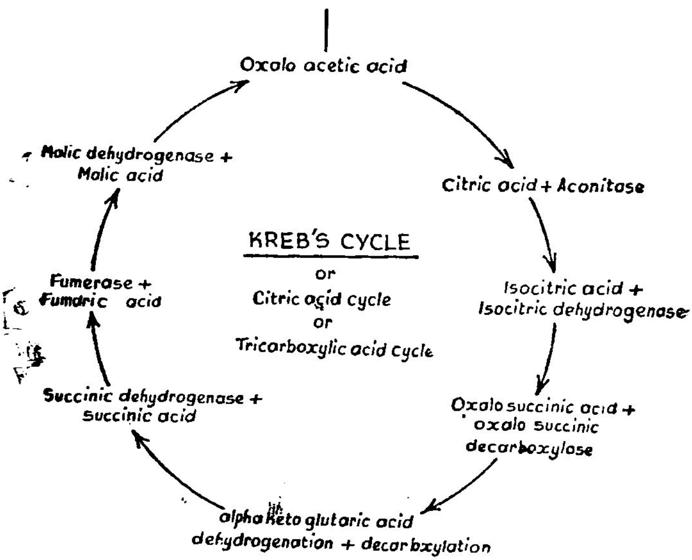
↓

= 2 molecules of Pyruvic acid + 2 A.T.P.

$$C_6H_{12}O_6 \longrightarrow 2(CH_3COCOOH) + 2\ A.T.P.$$

Pyruvic acid + Coenzyme A

= Acetyl coenzyme A




+ 36 ATP

Total 38 ATP

Fig. 79-b

transfer, an A.D.P (Adenosine di-phosphate) molecule becomes phosphorylated to an A.T.P. molecule (Adenosine tri-phosphate) This is called photophosphorylation. Besides Glucose is built up as a result of photosynthesis, which can be oxidised back to yield A.T.P. molecules.

A.T.P. is obtained during the break down of glucose molecule by respiration. One molecule of glucose yields 38 A.T.P molecules during the respiratory process. The break down of glucose is shown in the Kreb's cycle below. The first step i.e. glycolysis (breaking down of glucose to pyruvic acid) takes place in cytoplasm and other steps in Mitochondria. The break down is effected by a series of oxidation reduction processes, in what is known as electron transport system, involving many substances or enzymes like D.P.N. (Diphospho pyridine nucleotide) Riboflavin Coenzyme and Cytochromes.

## Chapter XVIII

# GENETICS

Apart from identical twins, no two humans are exactly alike. This applies to all living things. That variety is the spice of life is not only true of human experience but constitutes a principle inherent in the very nature of Nature. At the same time, it is also a common observation that the distinguishing characteristics of a given species is maintained generation after generation. This is heredity. Genetics is the branch of biology concerned with the manner in which inherited differences and similarities come into being between similar organisms. Though it has been known for quite sometime that there must be underlying natural laws which are responsible for heredity and variation, it was only in the beginning of the 20th century that an adequate scientific foundation was available. It has been established from the vast amount of data gathered in studies of genetics, that all characteristics of any organism have hereditary as well as environmental components, although some traits are more immediately influenced than are others.

### Methods of Genetic Study

Many techniques have been used by researchers in exploring the mechanisms of heredity and variation. The direct approach is experimental breeding; in human genetics study of twins, analyses and statistical procedures are more useful. Cytological investigations with regard to chromosome behaviour, biochemical and biophysical techniques to study the gene and its mechanics are basic to the study of genetics. In the laboratory, observations made on animals and plants have been most useful. Of these, the fruit fly (Drosophila melanogaster) is the experimenter's favourite, for it is possible to study 20 to 25 generations in a year. Biochemical and biophysical investigations have been done mostly on bacteria such as Escherichia coli, the common colon bacillus and viruses. Electron microscopes, microspectro photo meters and autoradiography have been valuable tools in these studies.

### Historical Background

Even in remote periods of history, men were making a conscious effort towards improved plant and animal breeding. Fantastic explanations of the mechanism of reproduction and sex determination were given. It was only with the development of the microscope in the later part of the 17th century that it was possible to discover the details of sexual reproduction and reproductive mechanism. This laid the foundation for the discovery of genetic mechanism. Rapid progress was made on the sexual reproduction in plants and animals and it was Mendel (1822–1884) who was able to throw light on the problem of Heredity. He is therefore called the father of Genetics and though his findings have since then been modified, his conclusions constitute the foundations of the modern science of Genetics.

### Mendel (1822–1884)

Father Gregor Mendel was an Austrian monk, who in his spare time experimented with plants in the Augustinian monastery garden at Brunn, of which he eventually became the abbot. After eight years of experiments and analysis Mendel presented his findings before the local Brunn scientific society in 1865 and published his results a year later. But the value of his work went completely unrecognized until 16 years after his death. In the year 1900, three different scientists, Hugo de Vries of Holland, Karl Correns of Germany and Erich Von Tschermark-Seysenegg of Austria, almost simultaneously brought the importance of his work to the attention of the scientific world. Mendel entitled his paper simply as "Experiments in Plant Hybridization". He did not announce it for what it was namely, the discovery of the age-old mystery of the laws governing the inheritance of traits.

Much of his success was due to the choice of material that he had selected for his investigations; viz., the garden pea or Pisum sativum which was an annual plant, with well defined characters and in which self fertilization was the rule. His good judgement in making crosses and studying the inheritance of separate traits, rather than whole complexes of traits was another factor which gave him successful results. Further he maintained a record of his results with great precision, in which his knowledge of mathematics and statistics helped him a great deal. He studied seven

pairs of characters in peas: (1) seed form (2) colour of seeds with coat (3) colour of seeds without coat (4) form of ripe pods (5) colour of unripe pods (6) position of flowers (7) length of stem.

Other geneticists who have contributed to our present knowledge in Genetics are Thomas Hunt Morgan (1866–1945), who received Darwin Medal in 1924 and in 1933 received Nobel Prize for his discoveries related to the hereditary functions of the Chromosomes, Sutton (1876–1916) Bateson and Punnet, H. J. Muller who received Nobel Prize for his discovery of the production of mutations by means of X-ray irradiation, Beadle and Taturn who received Nobel Prize in 1958 for their discovery that genes act by regulating specific chemical process, Pauling, and a host of others.

### Laws of Mendel

Soon after entering the monastery, Mendel began trying to develop new colours in flowers. In doing so he acquired considerable experience in artificial fertilization. His interest was aroused by the supervising and unaccountable results that he sometimes obtained. Whenever he crossed certain species, the same hybrid forms cropped up with striking regularity· But when he crossed one of his hybrids with another, some very different character sometimes appeared among their progeny. Others in his time had also noted this phenomena appearing with regularity. But Mendel, counted and figured the mathematical relationship of hybrid plants which was one of the main reasons for his success.

**Mendel's experiment:** Mendel planned his experiments with great care and foresight. He tried out enough plants to choose one, which had varied characters, each of which bred true to form, and which could be protected from foreign pollen during the flowing period. He found that the common pea was the best to meet his specifications for an experimental plant. His next job was to make sure of his material. He obtained 34 distinct varieties of peas and planted them in his monastery garden. Except for one, each variety yielded offspring exactly like itself. He repeated the plantings during the second year. The results were the same.

Having made sure of the raw material, he selected 22 plants and from these, seeds with seven sharply contrasting pairs of

characters. The following clear cut differences were selected by him:

1. Form of ripe seeds—round or wrinkled.
2. Colour of the seeds—yellow or green
3. Colour of seed coat—white or grey.
4. Form of ripe pods—inflated or constricted between the peas.
5. Colour of unripe pods—green or yellow.
6. Position of flowers—distributed along the stem or bunched at the top-axial or terminal.
7. Length of the stem—tall (6 or 7 feet) or dwarf ($\frac{3}{4}$ to 1–1$\frac{1}{2}$ feet).

*First step in experiment*

Each kind of seed was collected and in spring he planted them in separate plots. When they were ready to bloom, he opened the buds of 'wrinkled' plants, pinched off the stamens to prevent the peas from fertilizing themselves, and tied a little paper bag around each one to protect the exposed stigma. As soon as the pollen had ripened in the 'round' pea plot he collected the pollen and dusted it on the stigma of the 'wrinkled' pea plants. The flower was protected by a bag, from bees which may bring pollen from other flowers. To make certain that his experiments were not affected by which plant served as the seed parent, Mendel also reversed his fertilization procedure. Some of the pollen from the wrinkled peas was deposited on the prepared stigma of the round. Similarly all the other character-bearing plants were treated. Altogether he made 287 cross fertilizations on 70 plants.

**Observation**

The experiment which gave him the first result was the one in which he had chosen the colour of unripe pods-green or yellow. He found that, as the pods appeared, all of them were green, whether they came from parents that produced yellow pods or sprang from parents with green pods. That is, yellow and green parents alike had produced green offspring. Confirmation of this striking result came as the other characters he had chosen exhibited themselves in the next generation. In all the seven contrasting

characters he had chosen he found that, in each pair of contrasting characters, only one of them was evident in the next generation. He designated the hereditary trait that prevailed, as a *dominant* and the other trait that disappeared in the first generation (F1) or first filial generation as *recessive*.

*Second step in experiment*

Mendel's next step was to collect the first generation seeds or *hybrids* and to cross it with another hybrid. He did not operate on the buds but permitted the peas to fertilize themselves in the natural way and thus obtained a cross of two identical hybrids. Observation. He found that the trait that had disappeared in F1 reappeared in F2 (second filial generation). It meant that, that trait had not been lost but this heritage from the grand parents persisted and had come forth again. He counted the plants which showed the traits and found that in all cases the ratio of one trait of a contrasting pair to another was nearly 3 : 1. From 258 plants of seed colour he obtained 8023 peas. Exactly 6022 were yellow and 2001 green. Of 253 hybrid plants of the seed form, experiment produced 7324 peas, of which 5,474 were round and 1,850 wrinkled. Thus the average ratio of the entire group was three to one.

*Third step in experiment*

Mendel continued his plantings through six or seven generations in all cases. As he did so, he learned that the 3 to 1 ratio, which was based on the appearance of peas, was actually 1 : 2 : 1 ratio when the true nature of the peas was revealed by later plantings.

Mendel planted the wrinkled peas from the first hybrids in a separate plot. They yielded only wrinkled peas and continued to produce only wrinkled as long as he planted them and permitted them to fertilize themselves. They were pure recessives. But the round peas from the hybrids parents produced both round and wrinkled seeds. One fourth were true rounds and as long as they were planted, would yield only round peas. Two fourths were round in appearance, but were actually hybrids and would produce round and wrinkled peas in a steady 3 to 1 ratio. The wrinkled peas from the union were again pure wrinkled and never would yield anything but their own kind.

Thus it was clear that appearance meant little or nothing. **The surface differences of the offspring were great and yet below the surface lay still other differences and possibilities for variation.**

**Interpretation**

With the clarity and simplicity of a genius, Mendel labelled the 'dominant' in the union with a Capital A, and the recessive with a small *a*. A constant dominant thus would be formed by the coming together of two A's, and it would be described as AA; a hybrids by either *Aa* or *a*A; and a recessive by *aa*. With this understanding it was possible for him to chart this coming together and separation and the clearcut results that it produced. He had no way to look into the egg and pollen cells to search for the factors responsible for this hereditary pattern. But he reasoned out the biological basis that had to underlie them. He formulated three laws of inheritance from the above experiments.

1. All living things are a complex of a large number of independent heritable units–*Law of unit characters*

2. When each parent contributes the same kind of factor and the two come together in the offspring, a constant character is produced. But if one parent contributes one kind of factor, say *A*, and the other another, say *a*, a hybrid results. When the hybrid forms reproductive cells, the two differentiating elements segregate themselves again and thus are free to form new combinations in the next union–*Law of Segregation.*

3. The factors are unaffected by their long association in the individual. They emerge from the union as distinct as they entered it. This was Mendel's ultimately famous *law of the purity of gametes.*

The law of segregation is generally known as the first Law of Mendel and his experiments with one pair of contrasting characters as Monohybrid cross and the pattern of inheritance as Monohybrid inheritance. The 3 : 1 ratio is called Monohybrid ratio.

**Mechanism of Monohybrid Inheritance**

Mendel's experiment on one pair of characters viz. wrinkled and round peas may be graphically illustrated as follows:

| | | | | | |
|---|---|---|---|---|---|
| *Parent* | *Round* × *Wrinkled* | | | | —1st step in experiment |
| F-1 | all were round (hybrid) | | | | |
| F-1 | Round hybrid × Round hybrid | | | | —2nd step in experiment |
| F-2 | Round | Round | Round | Wrinkled | (3 : 1) |
| | ↓ | ↓ | ↓ | ↓ | |
| F-3 | Round | Round & Wrinkled | Round & Wrinkled | Wrinkled only | |

Interpreting the above using the principles of inheritance of Mendel, the monohybrid inheritance may be illustrated as below.

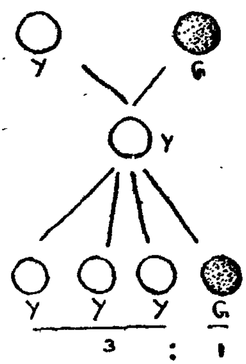


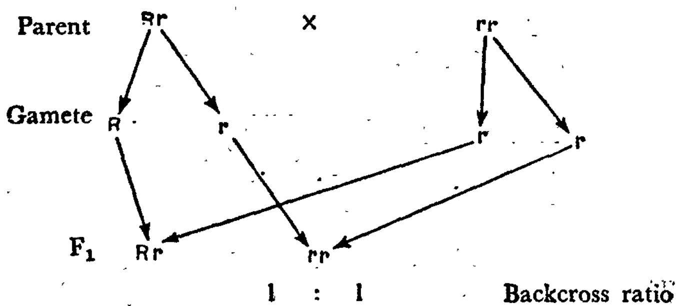

Fig. 80 Monohybrid inheritance
Y—Yellow G—Green

Let us assume that in each gamete there is a factor e.g. *R* or *r* (now known as gene) is present which is capable of determining a character in the offspring. In the zygote these factors are brought together at fertilisation (*RR* or *rr*) when the factors are identical as above they are called homozygous (*RR*) when they are different they are called heterozygous (*Rr*). A pair of contrasting characters are called allelic pairs or allelomorphic pairs, When a male with genic composition of *RR* is crossed with a female with genic composition *rr* or vice versa, the gametes of the parents

each with a single factor (due to meiotic division) unites with the gamete of the other sex (*Rr*) and forms a zygote. Since one of the contrasting characters is dominant and the other is recessive, they have round seed coats.

When the hybrid seeds (*Rr*) are planted and allowed to self fertilise, each hybrid produces two types of gametes, namely, *R* and *r*. Four combinations are possible *RR*, *Rr*, *rR* and *rr*. When they are observed, 3 of them (*RR*, *Rr*, *rR*) appear alike, since they possess the dominant factor *R* and have round seed coats while one of them *rr* shows wrinkled seed coat. Thus 3 : 1 ratio is arrived at. This is called phenotypical ratio. But when their genetic make up is examined, this ratio is modified as 1 : 2 : 1 ratio (genotypic ratio), *RR* and *rr* being pure and *Rr* and *rR* being hybrids, which in turn will split into 1 : 2 : 1 ratio again if self fertilised.

In order to verify his theory that hereditary factors remained distinct and issued unadulterated out of the hybridized pair, he performed a *test cross* or *back cross*. It is also a test to find the purity of an individual, whether it is of pure strain or hybrid. In this back cross, the hybrid (*Rr*) is crossed with the recessive parent (*rr*). He worked out the combinations that would result.




These results were obtained as predicted. Thus the most severe tests had been applied and Mendel's theory had been proved with a certainty that exceeded all expectations. Many such experiments have been performed since Mendel's time on Drosophila and more than 300 generations of this insect have been reared without contamination. The method of backcross has important practical applications in plant and animal breeding, and in producing disease resisting varieties of plants and animals. For example,

a particular type of tomato is of good quality but is not resistant to fungal diseases; whereas there is another variety which is small in size but is resistant to wilt. This is due to a dominant gene I. These two varieties *II* and *ii* are crossed and the hybrid *Ii* is again backcrossed with the recessive parent *ii*. Of the resulting plants *Ii* and *ii*, the heterozygous, immune plants are saved and the recessive ones discarded. By further breeding experiments, a pure breeding immune plant can be obtained.

**Modifications of Mendel's Law of Segregation:**

Since Mendel's time, science has advanced a great deal and our knowledge regarding the laws of inheritance has increased. Subsequent breeding experiments with a vareity of organisms showed that the principles laid down by Mendel were not universally applicable.

Mendel's principle of Law of unit characters did not apply to all cases, but there were several cases where one gene was not responsible for one character but a trait involved the combined action and interaction of many genes. Similarly, exception to Mendel's law of segregation were met with when the chromosomes failed to segregate and cases of nondisjunction were met with. There were also cases of incomplete dominance in several cases, as a result of which, the hybrid of the $F_1$ generation showed intermediate characteristics, the parental traits having blended in them. Classical example of incomplete dominance is seen in the 4 o'clock flower or Mirabilis jalapa, as shown by Correns. The flowers of this plant are red or white. Both types breed. If the two types of plants are crossed, the $F_1$ generation gives pink flowers showing incomplete dominance. If the hybrids are interbred red, pink and white flowered plants are obtained in the ratio of 1 : 2 : 1. The genes which thus express themselves in a partial and intermediate manner are called intermediate genes. Similar cases have been met with also in experiments with Andalusian fowls.

Though the expression of the genes is partial, there is no actual blending of the genes, neither is there any contamination of genes. When the pink flowered hybrid 4 o'clock plant is backcrossed with a recessive **homzygous** white flowered plant, 1 : 1 ratio of pink and white flowers are obtained thus confirming that the pink flowered plants are hybrids, with heterozygous genes.

Cases of incomplete recessive genes have also been met with. In a hybrid of example, the recessive gene has small effect when heterozygous.

**Modern Evaluation of Mendel's conclusions:**

1. Mendel considered a single gene to be responsible for a single trait. It is now known that many genes, perhaps all the genes present in an organism have something to do with each trait. Certain differential genes however are known to influence basic reactions and thus to be responsible for alternative end products or phenotype.

2. It is the genes that are inherited, not the traits. Genes behave as separate units whereas traits usually result from complex interactions involving many genes.

3. Dominance is not an inherited property of the genes but is influenced by factors in the external and internal and genetic environment. Dominance may be explained on the basis of modifiers or genes other than the one directly concerned that are present in the genetic environment.

4. Genes are in chromosomes and groups of genes sometimes behave as units.

## Dihybrid Inheritance

Being an excellent mathematician, Mendel was quick to note and pursue the revealing indication of order in heredity. He realised from the results obtained, that he was simply obtaining every combination that could be formed by the separate factors present. If *A* and *a* were combined, only one combination could be formed: *Aa*. If *Aa* and *Aa* came together, four combinations could be made: *AA*, *Aa*, *aA*, *aa* and this was exactly what happened.

If two series were united—$A+2Aa+a$ and $B+2Bb+b$, 16 different groupings could be produced. And as the dominants would determine the appearance of each group, the result would be 9*AB*, 3*Ab*, 3*aB* and 1*ab* as exactly what he found in the pods when he took two pairs of contrasting characters into consideration.

**Experiment:**

*First step:* Mendel crossed a variety of pea plant showing two pairs of contrasting characters–wrinkled seed, green in colour; and round seed, yellow in colour.

**Observation:** The hybrid offspring were all round and yellow. These are dihybrids.

*Second step of experiment:* The dihybrids were inter bred.

**Observation:** The $F_2$ generation were in the ratio of 9 : 3 : 3 : 1. His actual results were, 315 round and yellow, 101 wrinkled and yellow, 108 round and green and 32 wrinkled and green.

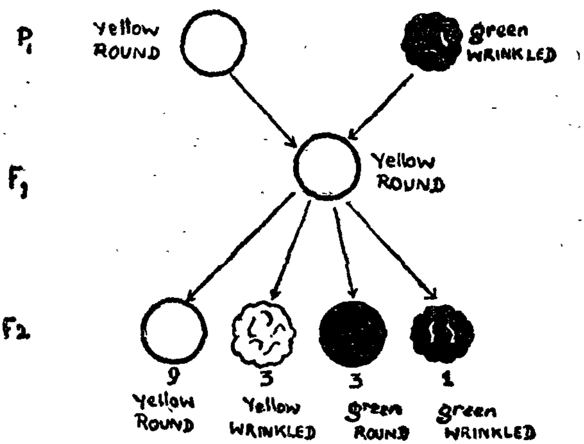



Fig. 81 Dihybrid inheritance

**Interpretation:**

The $F_1$ generation showed that the gene for round seed coat and yellow colour were dominant over the wrinkled seed coat and green colour. Let us assume that there is a separate gene for each character and that the genes occur in pairs in the cells of the plant. The two parent generations will have then a genic composition of *RRYY* (round and yellow) and *rryy* (wrinkled and green). Each gamete receives only one member of each pair of genes and, so, the gametes formed by *RRYY* will be *RY* and gametes formed by *rryy* will be *ry*. When they fuse, a zygote is formed of genic make up *RrYy* which is a dihybrid, expressing the dominant traits *R*

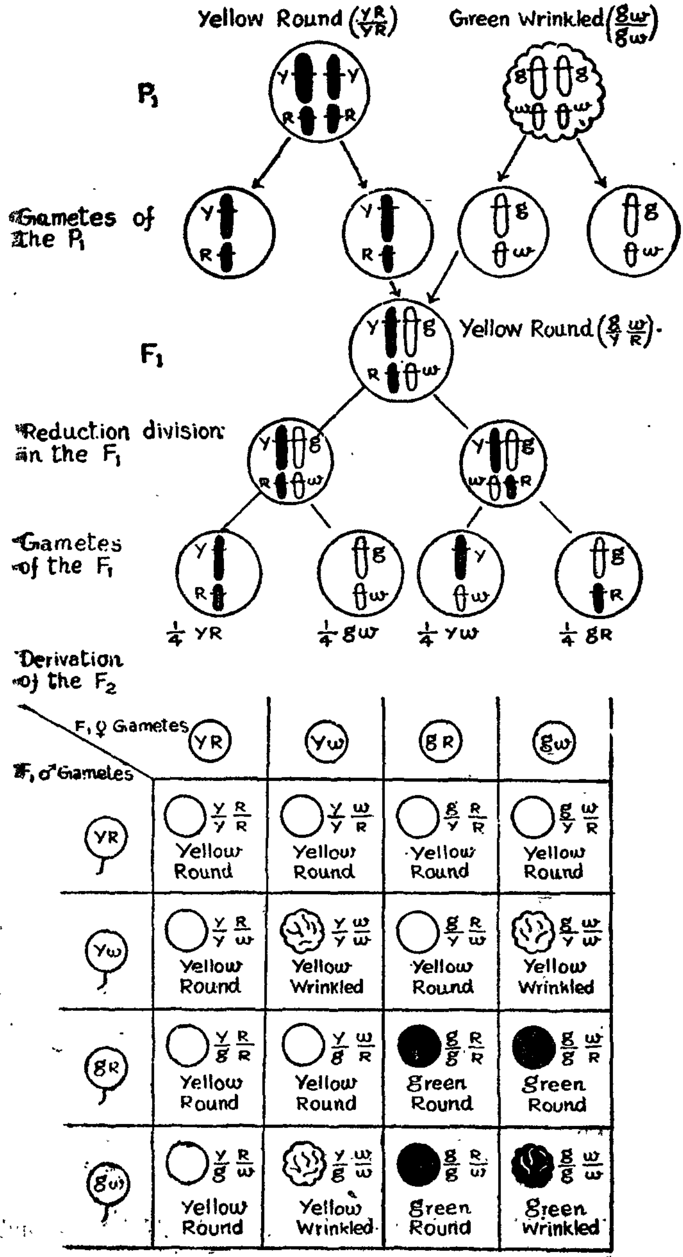

Yellow Round (YR/YR)
Green Wrinkled (gw/gw)
P1
Gametes of the P1
F1
Yellow Round (g/Y w/R)
Reduction division in the F1
Gametes of the F1
1/4 YR
1/4 gw
1/4 Yw
1/4 gR
Derivation of the F2
F1 ♀ Gametes
F1 ♂ Gametes
YR
Yw
gR
gw
Y/Y R/R Yellow Round
Y/Y w/R Yellow Round
g/Y R/R Yellow Round
g/Y w/R Yellow Round
Y/Y R/w Yellow Round
Y/Y w/w Yellow Wrinkled
g/Y R/w Yellow Round
g/Y w/w Yellow Wrinkled
Y/g R/R Yellow Round
Y/g w/R Yellow Round
g/g R/R Green Round
g/g w/R Green Round
Y/g R/w Yellow Round
Y/g w/w Yellow Wrinkled
g/g R/w Green Round
g/g w/w Green Wrinkled

*Fig.* 82 Table

and $Y$ (Round and Yellow). This hybrid can produce 4 types of gametes—namely $RY$, $rY$, $yR$ and $yr$. When two such hybrids are crossed, all the 4 kinds of male gametes have an equal opportunity of fertilising the 4 kinds of eggs. 16 possible zygotes will be formed which can be shown diagrammatically by checker board method introduced by the British geneticist R.C. Punnet.

**Inference:** By this experiment and others similar to it, using trihybrids, tetrahybrids etc. Mendel framed another law, called Law of *independent assortment* or the law of free recombination. It states that the pairs of alleles conditioning the different pairs of characters in the offspring are distributed independently of each other in the way they recombine in the formation of characters. New combinations as well as old ones of genes and traits will occur and it will be seen that every trait is inherited independently of every other trait.

It is further obvious that each gene behaves exactly as it does in a monohybrid cross. If, in the dihybrid inheritance, one pair of characters alone are taken into consideration, Mendel's result shows $\frac{3}{4}$ yellow and $\frac{1}{4}$ green (480.140) and $\frac{3}{4}$ round and $\frac{1}{4}$ wrinkled (423 : 123). This shows that the dihybrid inheritance pattern is not anything new but that it is merely a combination of monohybrids, each of which behaves just as it does when studied separately.

**Dihybrid backcross:**

To prove that the hereditary factors separated and recombined as indicated, he performed test cross with double dominants and double recessives. A dihybrid AaBb is crossed with AABB. The hybrid produces 4 kinds of gametes—AB, Ab, aB, ab whereas the other produces only one type of gamete, viz. AB.

| | AB | Ab | aB | ab |
|---|---|---|---|---|
| AB | AABB | AABb | AaBB | AaBb |

As each pair would contain a dominant, all should have round yellow seeds.

If the test cross is made with double recessive parent, the result is different.

| | AB | Ab | aB | ab |
|---|---|---|---|---|
| ab | AaBb | Aabb | aaBb | aabb |
| | Round yellow | Round green | wrinkled yellow | wrinkled green |

All the 4 types appear in equal numbers. In all his experiments, there appeared all the forms which the proposed theory demanded.

**Modifications of Mendel's Law of Dihybrid inheritance:**

As with Mendel's first set of principles subsequent work showed that Mendel's dihybrid ratio of 9 : 3 : 3 : 1 was not always achieved, due to lack of dominance in independent resortment, interaction of genes, and due to the effects of linkage of genes. Further it has been shown that a single gene is capable of exerting influence upon more than one character (pleiotropy).

The dramatic triple discovery of the work of Mendel by a Dutch, a German and an Austrian scientist and their simultaneous confirmation of his brilliant findings caught world-wide attention. The greatness of Mendel was recognized and one of the oldest desires of man, to know how the distinctiveness and the very form of living things are passed along from parents to progeny, was at long last satisfied.

## Chapter XIX

# MUTATION

Hugo De Vries (1901) was the first to suggest that there is a possibility of new types of inherited characteristics arising suddenly without any previous indication of their presence in the race. He came to this conclusion from the experiments conducted on the evening primrose, Oenothera lamarckiana. Since his discovery, it has been found that most of the variations he observed were due to rare cross overs between translocated chromosomes rather than to changes in the genes. Yet, De Vries deserves credit for the concept of mutation, since he was the first to suggest it.

Thomas Hunt Morgan (1910) made a scientific study of true mutations in Drosophila. He discovered a few white eyed Drosophila among the normal redeyed ones. By crossing this 'mutant', he was able to obtain a pure-breeding race of white eyed flies. This change in eyecolour proved to be produced by a single gene mutation which had occurred in an X-chromosome of a germ cell of the normal fly. Further scrutiny showed many similar mutations in Drosophila. The discovery of these made possible the extensive genetic studies on the fly.

**Nature of Mutations:**

The term mutation is often loosely used to denote all types of changes which result in a changed pattern of heredity. Two types of mutations are distinguished.

(1) *Gene mutations* or point mutations which involve change in the genes.

(2) *Chromosome mutations* or chromosomal aberrations which involve larger portions of the chromosomes (e.g. deletion, inversion, translocation and duplication).

**Gene Mutations:**

1. Gene mutations occur suddenly.

2. A mutated gene will be propagated through future generations, although there may be rare instances in which it reverts to normal. Thus the mutations are not permanent.

3. Gene Mutations play an important part in evolution in that they provide new characteristics upon which natural selection can operate.

4. Gene mutations can appear when there are small rearrangements or substitutions of the bases in the D.N.A. molecule.

5. The gene is stable, H. J. Muller estimated that there is an average chance of less than one in a million of any given gene undergoing a mutation in Drosophila from the time it is formed by a replication of genes. It must be remembered however that many mutations do not show visible effects and the number of chromosomes in Drosophila are only 4 pairs. Thus it can be estimated that there will be some sort of mutation for every 20 germ cells. However, all genes do not mutate with equal frequency.

6. Temperature and age influence the frequency of mutations.

7. Many mutations result in physiological changes with no recognizable effect on the body. For example mutation may affect fertility; most of them are lethal and there are also harmful mutations such as albinism, aniridia (defective iris in the eye) alkaptoneuria, amaurotic idocy etc.

8. A living organism is highly efficient but not perfect. Mutations represent random changes in the controlling mechanism of the living organism. It may be beneficial or not. The few beneficial changes which do occur provide a sufficient basis for evolutionary advance. Through selection, the many harmful mutations are held in check and eliminated, while the advantage held by the organism with beneficial mutation becomes established.

9. Mutations may not be essential to the survival of the species in certain limited conditions, but for most forms of life, mutations are essential.

10. Mutations may occur in germ cells, as well as in somatic cells. Cancer may be related to somatic mutations.

**Induced Mutations:**

Mutations are valuable to the plant and animal breeder for improving his stock. It is also valuable to the experimental

geneticist, for genes can be recognized and studied when animal occur.

H. J. Muller was the first to show the effect of X-rays on Drosophila, in speeding up the mutation rate. Since that time X-rays and other sources of radiation have become standard method of inducing mutation. Muller was awarded Nobel Prize in 1946 for his brilliant work in this field. Other sources of high energy radiation were tested for their mutagenic property. It was found that the radiation from radioactive isotopes of chemical elements would also increase mutation rate. Other agents such as ultra-violet rays, heat, chemical agents like nitrous acid, formaldehyde, ethyl-urethane, nitrogen mustard, phenol, manganous chloride, bromouracil and even cafeeine and theokromine can cause mutation.

Chromosomal aberrations can also be induced by radiation. Single break aberrations are usually lethal in their effects. Chromosome aberrations may result in phenotypic effects which are visible in the first generation after their occurrence, whereas most gene mutations are recessive and are not easily detectable.

Chromosome aberrations are the cause of sterility in those exposed to ionizing radiations. Gene mutations may also be involved in some cases. Observations in Hiroshimá indicate that many of the inhabitants of this city who received rather extensive radiation had no children for several years.

When a person is exposed to rather heavy but sublethal dose of radiation, certain parts of the body are affected much more severely than others. For example, the skin may become reddened, anaemia may develop due to reduced red blood cells etc. The actively growing and dividing cells are more sensitive to radiations.

*The cause of spontaneous gene mutations:*

Natural radiations from rocks, radiations in the food water and air taken in by animals or water, minerals and $CO_2$ taken in by plants may cause the naturally occurring genetic changes. Other forces supplement this action. There are fluctuations of energy within molecules, and it is possible that a concentration of this energy on one bond of the D.N.A. may cause breaks and rearrangements which could be mutations. Older parents transmit a slightly greater number of mutations to their offspring than younger parents.

## Chapter XX

# SEX DETERMINATION

For centuries, man did not know how the sex of the offspring is determined. However in the present century knowledge as to the mechanism involved in determining the sex of the offspring has developed enormously.

In the late 1890's scientists were beginning to establish the number of chromosomes in the cells of organisms. As a matter of regularity, all sexually reproducing organisms had in their cells, a diploid number of chromosomes (referred to as 2 N). In some insects, it was found that apart from the chromosome pairs an extra chromosome was also present and that too only in the males. This unpaired chromosome was named X chromosome. All the other chromosomes were called autosomes. Then it was discovered that the extra X chromosome had something to do with sex determination.

Today we know that at least 5 different sex determination mechanisms are there in the animal kingdom. They are (1) Haploid diploid type, (2) XO type, (3) XY type, (4) WZ type and (5) the non-chromosomal type.

**The Haploid diploid type:** During the production of gametes in sexually reproducing animals, the chromosome number is reduced to one half of what it is in the parent cell (i.e. a diploid cell gives rise to haploid gametes). During fertilisation, when two gametes meet the original diploid condition is restored. In honey-bee, ants and wasps, fertilised diploid cell develops into a normal female. If the egg cell is not fertilised it grows into a male. Thus the males are haploid and females are diploid. The males produce gametes by mitosis only so that the male cells are haploid. The female produces gametes by meiosis, creating haploid egg cells.

**The XO type:** In grasshoppers and in some insects the males have a set of diploid autosomes plus only one X chromosome. The females have a set of autosomes and 2 X chromosomes. The

female produces egg cells, all of which have a haploid set of autosomes and one X chromosome. The male produces sperms, half of which have a haploid set of autosomes only and the other half have a haploid set of autosomes plus the extra X chromosome. Fertilisation results in 2 types of zygotes. One set with 2 X chromosomes forming a female and another set with only one X chromosome forming a male.

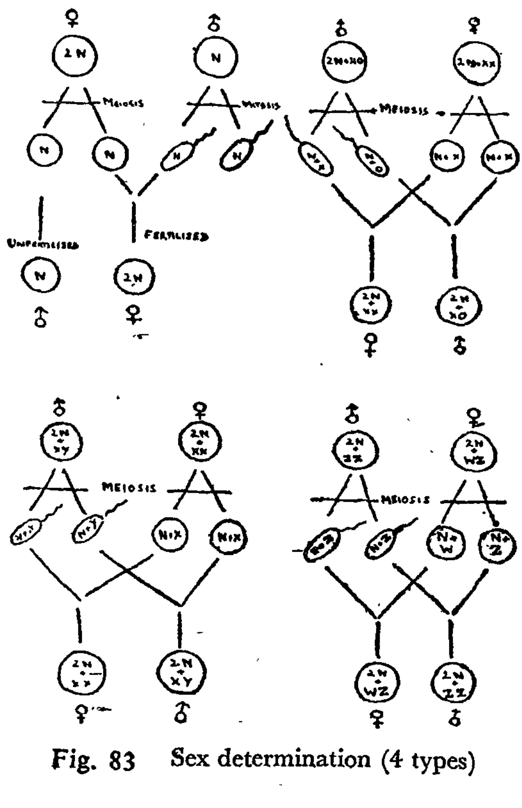


Fig. 83 Sex determination (4 types)

**The XY type:** In Man, some mammals and insects like Drosophila, the body cells of the male have a set of autosomes plus one X chromosome and another Y chromosome. This may be slightly different from the X chromosome and carries very few genes. During spermatogenesis the males produce two types of sperms, one type with an X chromosome and another type with a

Y chromosome. But the female which has two X chromosomes besides autosomes, produces similar egg cells, all of which have one X chromosome beside a haploid set of autosomes. Depending upon whether an X bearing sperm or Y bearing sperm that fertilise, the egg cell, the sex of the offspring is determined. If an X bearing sperm fertilises the egg cell than the zygote is XX and a female. On the other hand if a Y bearing sperm fertilises the egg cell, then the zygote is XY and a male.

**The WZ type:** This is just opposite to the type described above. The female produces 2 types of gametes while the male produces similar gametes. For convenience we can say, that females are ZW and their gametes are either Z bearing or W bearing besides autosomes. The males are ZZ and all the gamete are Z bearing. The zygote that becomes ZW becomes the female and which is ZZ becomes the male. This type is found in birds, butterflies etc.

**The non-Chromosomal type:** In some animals the sex determination is not dependant on chromosomes. Environment and physiological conditions seem to determine the sex. Some mollusca are males but as they grow older they become females.

One interesting case of sex determination is that of a marine worm called Bonellia. The female is a bigger worm with a long proboscis. The male is very microscopic and lives in the genital duct of the females. If the zygote settles down independantly it grows into a female. If it touches a female worm, then it grows into the deminutive male worm. Hormones from the female's body seem to interfere with sex determination.

At the first glance, it appears that the heterosomes or the sex chromosomes play the decisive role in determination of sex. But later researches have proved that they are not the only factors. The proportion between the autosomes and heterosomes or the ratio of sets of autosomes to X chromosomes determine the sex of the individual.

## Chapter XXI

### Blood Groups (ABO Rh Systems)

The first serious medical attempts at replacing human blood of victims who had suffered serious blood loss were unsuccessful, and evoked severe reactions and often death. In 1900, Karl Landstenier discovered the explanation for these adverse results as due to an aspect of immune response.

Each kind of micro organism, contains a wide range of macromolecules which act as antingens. If and when a particular antigen gets into the body, it stimulates certain cells, derived from lymphocytes, to produce a corresponding protein called an antibody. The antibody combines with and in some way neutralizes the antigen, destroying the microorganism in the process. This can take place in several different ways but generally the antibodies either stick to the surface of the microorganisms, making them clump together (agglutination) or they may cause them to burst (lyse). The production of antibodies in response to antigen is called the *immune response.*

In man, any living material, introduced into the body is treated by the recipient as 'foreign' and antibodies react against it. When the blood of one person is transferred to another, if the blood of the two individuals is not compatible, the donor's RBC's clump together in groups (agglutination) which may result in blockage of the recipient's blood vessels. This is because antigenic substances called agglutinogens are present on the surface of red blood cells,, which are complementary to antibodies present in the recipient's plasma. Unlike normal immune responses, the recipient does not actually produce antibodies in response to the donors blood. They are present all the time, agglutination occurring if the donors blood happens to contain the corresponding antigens. Each individual usually has antibodies against those red cell antigens that he lacks. Why? The answer is not entirely certain. Perhaps we are all exposed to substances (in our food, from injection or from bacteria living in our intestine) that have antigenic

determinants similar to A and B. We would proceed to synthesize antibodies against them if they did not resemble 'self' but not if they did. Certainly materials carrying A-like or B-like antigenic determinants turn up from time to time (e.g.) as contaminants in vaccines.

**ABO System**

The antigens or agglutinogens on the red blood cells are called the A and B antigens, and the blood types have been classified into A group (having antigen A), B group (having antigen B) AB group (having both antigens A and B) and O group (having neither).

The basic principle to be observed is that the blood introduced into the patient's body must not contain RBC's which can clump. It is not serious if the introduced blood contains antibodies against his own RBC's because the antibodies will quickly be diluted by his own plasma. Hence type O blood has been called the '*universal donor*' because O red cells cannot be clumped and the antibodies will be quickly diluted by the recipient's plasma. Similarly AB blood is called the *Universal recipient's* because it contains no antibodies to clump RBC's introduced into it. (Table 1 and 2 given below).

**TABLE 1**

**Summary of reactions that occur when Bloods of Different Groups are mixed**

| | | Oab | Ab | Ba | ABo |
|---|---|---|---|---|---|
| | Oab | — | — | — | — |
| | Ab | + | — | + | — |
| Donor | Ba | + | + | — | — |
| | ABo | + | + | + | — |

*Key*:—

+ = agglutination
— = no agglutination
Capital letter = antigens in corpuscle
Small letter = Antibodies in plasma.

## TABLE 2

### ABO System

| *Blood group* | *Antigens in RBC* | *Antibodies in Plasma* | *Can donate to* | *Can receive from* |
|---|---|---|---|---|
| A | A | Anti B (b) | A, AB | O, A |
| B | B | Anti A (a) | B, AB | O, B |
| AB | AB | Neither | AB | O, A, B AB |
| O | O | Anti A & Anti B (ab) | O, A, B AB | O |

In actual practice doctors prefer to match blood types exactly when carrying out blood transfusions.

### Agglutination tests for Blood groups

On a glass slide, is placed a drop of type A serum (containing 'b' antibody) and a separate drop of type B serum (containing 'a' antibody). When a drop of type O blood is added to each drop (O blood has neither A or B antigens) there is no agglutination of

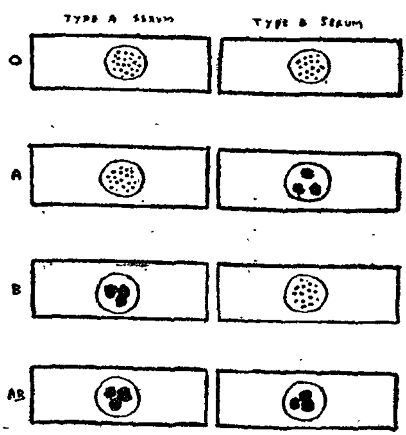



Fig. 84

red cells in either drop. If a drop of type B blood is added, agglutination occurs with type A serum; type A red cells are agglutinated by type B serum and type AB cells are agglutinated by both sera.

## Applications

These blood types are genetically determined and do not change during a persons life-time. Determining the blood types of the individuals involved may be helpful in settling cases of disputed parentage (Table). Such blood tests can never prove that a certain man is the father of a certain child, but only whether or not he *could be* its father. They may definitely prove that he could not be the father of a certain child.

**TABLE 3**

**Exclusion of Paternity based on Analyses of Blood Groups**

| *Child* | *Mother* | *Father must be of Type* | *Father cannot be of Type* |
|---|---|---|---|
| O | O | O, A, B | AB |
| O | A | O, A, B | AB |
| O | B | O, A, B | AB |
| A | O | A, AB | O, B |
| A | A | A, B, AB, O | — |
| B | B | A, B, AB, O | — |
| A | B | A, AB | O, B |
| B | A | B, AB | O, A |
| B | O | B, AB | O, A |
| AB | A | B, AB | O, A |
| AB | B | A, AB | O, B |
| AB | AB | A, B, AB | O |

With the development of techniques for determining the blood types of mummies and even of skeletons, the use of blood tests in anthropology has been considerably broadened.

**Distribution of Blood types**

Some notable difference have been found in the relative frequency of the different types in different races. The proportion of blood types in a population remains constant from one generation to the next as long as there is no inter marriage with other groups.

In the ABO blood type system, O is the most common type; it is found in over 50% of individuals of most populations. Type B is almost completely absent in American Indians and Australian aborigines, but become increasingly common in Europe, Africa, India and Asia. With its high frequency in Asia, type B is often called the 'Asian gene' and some people believe that it was distributed from Asia to Europe by the successive waves of invasion by Mongols. Blood type A is actually of two types—A1 and A2. A1 occurs in American Indians, Asians and Pacific islanders and Australian aborigines while A2 is limited almost completely to Europeans and their descendants.

To summarise, B and A2 are almost completely missing in American Indians, B is low and A2 high in Europeans, B is high and A2 is rare in Asians while Australian aborigines, American Indians and Polynesians all have no A2 and little B.

**Transfusion of Blood**

The transfusion of whole blood, plasma or plasma fractions is extremely important in saving lives. Blood drawn from a suitable donor is treated usually with sodium citrate (which binds the calcium ions) to prevent coagulation. Care must be taken to prevent infection and the blood must be introduced into the recipient's veins at the proper temperature and rate. The heart will be overloaded if blood is transfused too rapidly. Blood can be stored for weeks in a "blood bank" by adding citric acid and glucose and keeping the blood at a temperature of 4 to 6°C. By separating the red cells from the plasma and then suspending the cells in purified albumen, cells can be kept for, as much as three months.

The search for substitutes for whole blood to be used in transfusions dates back to 1878. Plasma and certain fractions, which can be stored much longer than whole blood are effective substitutes for whole blood in many clinical conditions such as shock.

Dried plasma and plasma fractions prepared by freezing and drying and placed in a sealed sterile container can be kept even without refrigeration for a long time. To be used, the plasma is mixed with proper quantity of sterile water and injected. In preparing plasma, bloods from sixteen different people of assorted blood type are pooled so that the different agglutinins are diluted below their effective concentration and will not agglutinate the red cells of the recipient.

The polysaccharide dextran, a glucose polymer made by bacteria can also be used as a blood substitute. It can be prepared inexpensively in large amounts, does not cause agglutination of red cells, gives fewer toxic reactions then any other substitute tried and eliminates the possibility always present in the transfusion of blood or plasma of transmitting the virus of serum hepatitis. Gelatin, pectin, gums and albumin from cows blood have all been tried as substitutes but none has been satisfactory.

**Rh factor**

In addition to the ABO system, many other blood groups are now recognised. These include the Rhesus system, so called because it was first discovered by injecting rabbits with red cells obtained from the Rhesus monkey.

The majority of people possess RBC containing an antige called the Rhesus factor. Their blood is described as RH positive. Those who lack Rh antigen are called Rh negative. Unlike the ABO system, Rh negative blood does not automatically contain the Rh antibody. However if Rh positive blood finds its way into a Rh negative recipient, the latter responds by producing the corresponding Rh antibody. Nothing further happens; but if the Rh negative recipient subsequently receives another dose of Rh positive blood, these Rh antibodies will cause agglutination of the donors red cells, often with fatal results.

**Problems in Pregnancy**

Problems arise in babies born to Rh− mothers and Rh+ fathers. The foetus will be Rh+. The Rh antigen in the foetus and blood cannot get across the placental barrier into the mothers

blood during pregnancy, but can, at the time of birth. Then, the mothers immunity system mobilizes lymphocytes into immunocytes that produce antibodies against the Rh antigen. Since this occurs after the birth of the first baby, the first born is not usually affected unless the mother has already had antibodies against Rh, produced from previous exposure to Rh antigens in injections or transfusions. However the second born will receive antibodies against Rh from the mother across the placental barrier before birth.

Just before birth, Red cells pass from an Rh+foetus to its Rh−mother through placenta, and maternal white cells produce anti Rh+antibody.

The mother retains antibodies against Rh.

In subsequent pregnancies, mother's antibodies destroy baby's red blood cells.

These antibodies clump RBCs of the foetus and can cause either mild symptoms or severe interference with circulation and the baby may die before birth or survive and suffer jaundice

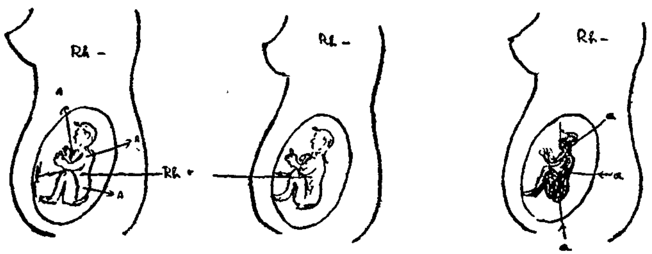



Fig. 85 (*a*) Fig. 85 (*b*)

Rh—Factor

Diagram of the sequence of events leading to Erythroblastosis fetalis, the clumping of red cells of the foetus within the uterus.

and liver failure. Occasionally the baby will be deaf or mentally retarded. The condition in the foetus brought about by the Rh incompatibility is called erythroblastosis foetalis and may be fatal unless the child's blood is replaced by transfusion with Rh-blood. Nowadays such transfusions are common practice and can be carried out while the foetus is still in the womb. It

has recently been found that hemolytic disease can be prevented by treating the mother with an anti Rh-globulin that coats the foetal cells, thus blocking the Rh factor.

**Distribution**

Rh negative is highest in W. Europe and rare in Asia. About 85% of white people are Rh positive.

## Chapter XXII

# EVOLUTION

### Introduction

The term Evolution literally means opening out, rolling out or unfolding and refers to all such changes occuring in every field. The process is similar to the blossoming of a flower from its bud condition. To be more precise, it is the gradual development from the simple unorganised condition of primal matter to the complex structure of the physical universe ; and in a similar manner from the beginning of organic life on this habitable planet, to a gradual unfolding and diversification into the varied forms of beings which constitute the animal and the plant kingdoms. The former is termed Inorganic Evolution and the latter Organic Evolution.

Various theories have been proposed at different times to explain the great diversities of the fauna and the flora inhabiting this planet. Most of these are purely speculative and hence only of historical importance and these are (1) the theory of eternity of present conditions ; (2) the theory of special creation and (3) the theory of catastrophism. The modern accepted theory is the theory of Organic Evolution.

### The Theory of Eternity of Present Conditions

According to this theory the universe is unchangeable and so too the organisms inhabiting the universe have also been existing without any change and will continue to exist in the same state throughout eternity.

### The Theory of Special Creation

One of the greatest advocates of this theory which is of biblical origin was a Spanish priest by name Suaroz. He suggested that the world was made in six days by the Creator. This view was for a long time believed by several thinkers including Linnaeus.

## The Theory of Catastrophism

When fossils were discovered during the 19th century serious problems arose against the acceptance of the theories of eternity of present conditions and special creation. Therefore to explain these problems the theory of catastrophism was proposed by Cuvier (1769–1832) regarded as one of the founders of the Science of Palaeontology. He suggested that there were periodic world wide cataclysms during which all living forms were destroyed and that these were succeded by fresh creations.

## The Theory of Organic Evolution

This theory states that the present day complex forms have evolved or descended by a gradual process of change from the simple forms of the past. Thus the process is summarily a process of gradual change with descent. Although dynamic in nature, it is such an extremely slow process, that the short span of one's life makes it rather impossible to detect the small evolutionary changes occurring in various organisms. However one could draw inferences by observation of several successive generations, in those instances where each generation is of short duration.

The fact of Organic Evolution can be substantiated by marshalling evidences from different disciplines of biology such as morphology, embryology, palaeontology, physiology and biochemistry, genetics, biogeography and taxonomy.

## Evidences in Support of Evolution

Several evidences have been set forth to demonstrate the facts of evolution and many theories have been postulated to account for the process. Some of the evidences are more direct and hence free from a purely interpretative construction than the others. Some are primary and foundational, while some others are rather inconclusive even though they may serve to confirm other facts. In any case all these evidences are directed towards the single aim of proving the facts of organic evolution. Several disciplines of biology yield evidences for the fact of organic evolution. Comparative anatomy, embryology, palaeontology, physiology, biochemistry, biogeography and taxonomy have usually been presented as the evidences since they enable us to arrive at certain positive inferences. In recent times evidence

for the fact of organic evolution has also been drawn from genetics. The hereditary determiners namely the genes undergo mutations bringing about hereditary variations which constitute the raw materials of evolutionary change.

**Evidence from Comparative Morphology and Anatomy**

Similarities in structure between groups of organisms are generally accepted as indications of relationship. When we study and compare the structures found in various animal groups we come across different plans of structural organisation which characterise the different groups. Thus, for example, we know that vertebrates and invertebrates are more widely apart than fishes and birds or annelids and arthropods. The invertebrates possess a great variety of structural patterns so that at first sight the structures found in various invertebrate groups may not appear to be related. For example, in the prawn on the ventral side of the abdomen there are appendages called the swimmerets, each made up of a basal piece attached to which are two limbs. Since there are two lobes or limbs it is described as a biramous appendage. Although the swimmeret is strikingly different in its external appearance and in its function from the other appendages it serves as the basic type from which the other appendages such as the walking legs, the mouth appendages, etc., could be derived. Theoretically therefore the ancestor of the crustaceans may have been equipped with similar biramous appendages which in course of time became modified to serve a variety of functions. In just the same manner the mouth parts of insects furnish another remarkable instance of modification of fundamental pattern. This pattern consists of the labrum, labium, maxillae, mandibles and hypopharynx. From this fundamental pattern have evolved, the chewing type of the grasshoppers, cockroaches, etc., the tubular sucking types of butterflies and moths and the piercing and sucking type of mosquitoes in order to suit their respective modes of food procurement.

In the vertebrata, comparative anatomical studies reveal a fundamental unity of plan in the various structures. For example the vertebral columns of all vertebrates show similarity in the basic plan of construction of the vertebrae. A centrum, a neural arch and the other processes for the attachment of muscles

form the basic structures of similarity among the different vertebrae. Cyclostomes which are the most primitive of living vertebrates show only two pairs of dorsal arcualia right from the embryonic condition and they remain as such even in the adults. In the chondrichthyes (sharks, etc.) a further increase in complexity of structure is observed, in that the neural arches are developed and a centrum is formed around the notochord. In osteichthyes (teleosts) the vertebrae are ossified either partly or wholly. In these the presence of the hypocentrum and pleurocentrum are characteristic. In rhipidistia an extinct group of lung breathing fishes which gave rise to the amphibia, the formation of two centra has been noticed. Fossil amphibians had a similar pattern of vertebrae. In modern amphibia, the hypocentrum gradually replaces the pleurocentrum and zygapophyses are added to the vertebrae. In the ancestral reptiles also the pleurocentrum gradually replaces the hypocentrum. The vertebral column of mammals differs mainly by the development of curvatures associated with the mechanics of locomotion. All these seem to denote that the vertebral column of vertebrates is based upon a prototype which varies from class to class depending upon the type of locomotion.

Likewise, a comparative study of the forelimbs of different vertebrates reveals how strikingly they exhibit a fundamental plan of similarity in structure even though they show to a great extent gradual adaptive modifications. The forelimbs of a frog, a reptile, a bird and several mammals such as the bat, the whale, the cow, the horse, the dog, the monkey and man are found to exhibit a strikingly similar anatomical similarity with each other. In all these vertebrates the skeletal framework of the forelimb is made up of similar bones such as the humerus, radius, ulna, carpals, metacarpals and phalanges. These components show only little variations in the different vertebrates due to functional adaptations. The forearm of a frog helps in hopping, that of a reptitle in crawling, that of a bird and a bat in flying, that of a whale for swimming, that of a cow for walking and that of a horse for running etc., In addition to this skeletal similarity observed, there is a surprising similarity even in the arrangement of the principal muscles, nerves and blood vessels of the forelimbs of the various vertebrates. Such structures, in spite of their functional variations, maintain their typical anatomical character

In every case the deviation from the basic structural plan is dependent on the length of time during which the divergence has taken place. Such structures which are similar in origin but perform different functions are described as homologous structures. This phenomenon is known as homology and it indicates relationship. As contrasted with this are the analogous structures which are externally alike and perform similar function but have different embryological origin. For example the wings of a bird and a fly are analogous and do not indicate any structural relationship. In short homologous structures indicate relationship while analogous structures do not. Analogy signifies merely coincidence of function. Analogy leads to convergent evolution while homology brings about divergent evolution.

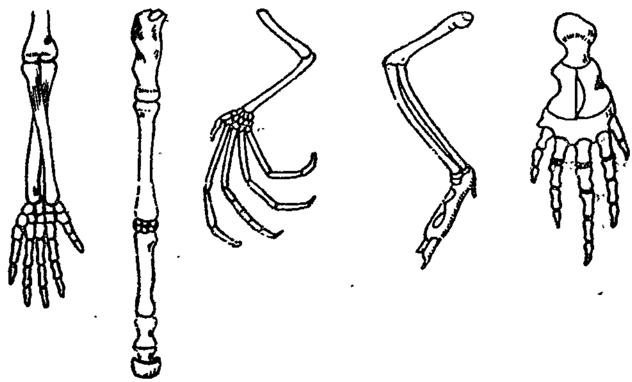



**Fig. 86.**

Comparing the anatomical organisation of the vertebrate limbs mentioned above, it is found that the fundamental similarities are deep seated. The arrangement of the various bones, the structure of the muscles connected with them and the nature and distribution of the nerves all indicate marked resemblances. Superficially however they are entirely unlike each other and are used for different purposes. The human hand for instance is a prehensile organ with five nail tipped digits and it rotates on a flexible wrist with eight carpal bones. The ulna and the radius of the forearm are two separate bones articulated with the single bone the humerus which fits into the glenoid cavity forming a ball and socket joint. The humerus, the forearm

and the hand of man are so moulded as to perform a multitude of functions whereas in the case of horse it uses the corresponding homologous structures only for one purpose and that is, locomotion which requires only a forward and backward movement in one plane. So, in the horse we find only one digit with its nail considerably enlarged to form the hoof. The other digits occur as rudimentary or vestigial structures. Again, the carpals are fused and there are only seven carpals. The radius and the ulna are fused into a single bone and the joint is of the hinge type. In the wing of the bat we find the same pentadactyl plan of construction except that the bones are much elongated especially the phalanges and are connected with each other by the patagium, which is attached also to the legs and the short tail. The digit corresponding to our thumb is free and provided with a claw. In the birds there is a great fusion of digits, the carpals and the metacarpals, as also an elongation of the bones particularly in the soaring birds. Here, the function of the membrane of the bat's wing is accomplished by the feathers. From the evolutionists' point of view, these animal types have come to acquire the modifications, mentioned due to evolutionary changes. To believe that each of these animal types have acquired their respective limb patterns independently is entirely illogical. Thus comparative anatomy provides ample evidence in support of the concept of organic evolution.

Even the brain of man has its various divisions plainly foreshadowed in such creatures as the fish and the frog. It will be observed that all these have olfactory regions except where these have been secondarily lost, (as in the aquatic cetaceans the whales, and the porpoises); cerebral hemispheres; pineal outgrowth (above); infundibular region (below); optic chiasma (crossed optic nerves, below); and optic lobes; a cerebellum and a medulla oblongata tapering gradually into the spinal cord. A more careful study of the brain of different vertebrates would reveal many additional and even minute homologies, such as the distribution of fibre tracts in brain and spinal cord, the cerebral ventricles and their connections, and the connection of the paired cranial nerves (vertebrates) to the different parts of the brain. The most noticeable difference between the brain of the lower and higher vertebrates is the disproportionate increase in size of the cerebral hemispheres and the cerebellum in the latter.

Presence of homologous organs lead us to the inescapable conclusion that they must have descended from a common ancester as otherwise they cannot inherit the same fundamental plan. This is in keeping with the common cardinal genetical principle like begets like.

The only rational conclusion that could be drawn from these evidences is that groups of organisms originally belonging to the same species have diverged sufficiently time after time throughout biological history from the ancestral types to be considered as new species. The most conspicuous deviations from the primitive condition occurs in those parts which are most directly influenced by the environment. Adaptational changes which survive and persist biologically are usually those which are beneficial to the organism in its changed ecological niche. Therefore the internal anatomy reveals the biological history of the animals while the external form indicates the nature of the environment occupied by their ancestors.

**Vestigial Organs**

Additional anatomical evidences are furnished by what are known as the vestigial organs, *i.e.*, structures which are apparently of no use to the possessor and hence not necessary for its existence. This can be best explained by the following analogy. If a propeller operated boat has some parts of a paddle driven one, such as a paddle box or a paddle post only two conclusions are possible *i.e.*, either the designer was crazy or that the boat is a conversion of a paddle type to the propeller type. Clearly the latter conclusion is the only reasonable one. In just the same way in the animal world also vestigial organs may be considered as remnants of structures which were well developed and functional in the ancestral types, but which are in the process of disappearance in course of evolution due to their non-utilitarian value. In other words, a change in the environment may render ineffective the usefulness of certain organs developed in response to a set of previous environmental factors. However, such organs may persist in the body having lost their original functional significance in a reduced form and in the process of gradual elimination. The term *vestigial organ* is applied to such persistant non-utilitarian structures.

A number of examples for such vestigial organs can be cited. According to Weidershein there are as many as 180 vestigial structures in man. The oft cited examples are the reduced caecum and the vermiform appendix, the coccyx, the wisdom teeth, the nictitating membrane of the eye, the body hair and the muscles that move the ears. The human appendix, for instance, is the remnant of a blind pouch the caecum which is large and functional in the digestive tract of herbivorous animals like the rabbit. Food materials rich in cellulose require a long time for digestion and the caecum provides a place where the food may be stored while the gradual process of digestion, mostly by the intestinal bacteria, takes place. During the long period in the evolutionary history, animals have gradually changed to a diet containing more meat and less-cellulose and correspondingly the caecum seems to have gradually diminished to the present useless vestige, the verniform appendix. Associated with the ear lobes in man there are groups of functionless ear muscles which correspond to those that move the ears of the horse and dogs. This is because of the fact that in the latter the ear lobes have to be moved in all directions to pick up sound vibrations. In man, on the other hand, evolution has progressed towards the perfection of the hearing mechanism to such an extent that this mechanism is dispensed with and the muscles persist as vestiges. The nictitating membrane characteristic of the lower vertebrates has lost its function in man but is represented as a small nodule of flesh plica semilunaris at the inner corner of eye. The tail which is so useful and characteristic of arboreal animals has lost its functional significance in man due to the adoption of a terrestrial node of life and hence persists as a vestigial structure called the coccyx. Another interesting vestigial structure in man is the wisdom tooth. This is fully functional in the primates, but in man it is for more variable than the other tooth to its size and time of eruption. In some it may not erupt at all.

There is a tendency on the part of the land birds inhabiting Oceanic Islands to lose the power of flight. One of the most interesting example is the Kiwi or Apteryx of New Zealand in which no trace of the wings is visible externally. However, a careful scrutiny reveals the presence of a minute rudiment concealed beneath the long hair-like plumage on either side. In the closely

related extinct mass even this rudiment has disappeared. Similar instances are observed in many species of flightless insects. The python has two claws, one on each side of cloaca supported by slender bones. These claws are considered to be the vestiges of hind legs which were functional in their ancestors. Further many snakes have only one functional lung, the other being represented by a small rudiment only. In many cave dwelling fishes the eyes although present have become non-functional due to the prevailing darkness in the caves and consequently their non-utility. Whales have developed enormous tail flukes to propel them through water and although the hind limbs have apparently vanished, under the skin there are vestiges of the pelvic bones and limb rudiments.

Many vestigial structures are much more fully developed in the embryo than in the adult. For example, the embryo of the whale is densely clothed with hair although the adult is devoid of hairs except for a few friging the mouth and the eyes. The adult whale bone whales have no teeth but their embryos have numerous teeth which are absorbed before they erupt. In the sheep the collar bone is present only in the embryonic condition and it degenerates later. Similarly in certain species of beetles in the embryos, pairs of legs develop in the abdominal region as well as on the thorax, only to disappear later.

Another classical example of a vestigial organ is the pineal gland of the vertebrates. It arises as a median dorsal outgrowth of the forebrain (diencephalon) and exhibits both glandular and nervous characteristics. Except in the lampreys and Sphenodon where this structure resembles the third eye, in all the other vertebrates it is present only as a vestigial structure. This indicates the possibility of the possession of a pineal eye in the ancestral forms.

**Evidence From Embryology**

Embryology deals with the study of the development of individuals from the egg to the adult stage. The different stages in the development of the individual organs are collectively known as its ontogeny (on being genos-descent) and the study of the history of development of a species or race is called its phylogeny. Embryological studies are of considerable importance since they

provide ample proof in support of the theory of organic evolution. The first stage in the ontogeny of an organism is the unicellular egg stage which may be considered as corresponding to the protozoan ancestor and it has been observed that the preliminary course of ontogeny in different animals belonging to different classes, namely the fishes, amphibians, reptiles, birds and mammals

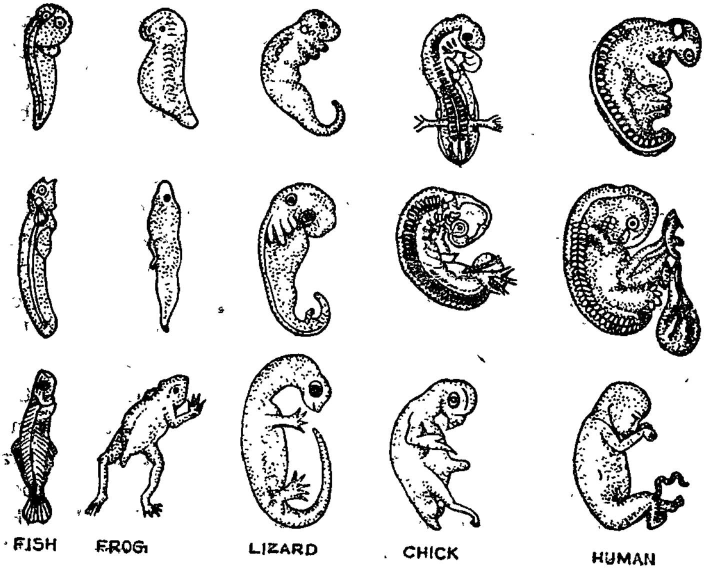



Fig. 87

shows certain similarities. Thus, in all cases clevage of the egg occurs immediately after fertilization as a result of which the fertilized ovum divides into 2, then 4, 8, 16, 32 and ultimately into a mass of aggregate cells which remain attached to each other to form the blastula. Gastrulation then occurs during which the germinal layers (ectoderm, endoderm and mesoderm) are established and the fate of these layers in all cases of vertebrates is very much the same. A detailed study of the embryonic development of different forms makes one think that there is in all cases a close correspondence or affinity. For instance, the young embryos of different vertebrates greatly resemble each other. All of them including the human embryo possess long tails and gill-slits. In fact it is even difficult to distinguish human embryo

from that of a bird or an amphibian in the early stages. The differences are less in case of groups which come close together when they are classified according to their organizational level. For example, the differences between a fish and an amphibian will be much less than those between a fish and mammal.

Again, the manner of development of the various organs in the various classes of vertebrates shows a striking similarity. For example, the kidney develops in all vertebrates as a set of tubules or nephrons, from the anterior end backwards in a series. The embryonic kidney is constituted by the pronephric tubules which develop behind the otic region during ontogeny in all the vertebrates. However, they do not form the adult kidney in any vertebrate (except Myxine). Another set of tubules, the mesonephros which arises behind the pronephros, constitutes the adult functional kidney in the fishes and amphibians. Still another set, the metanephros, develops posterior to the mesonephros and this constitutes the functional kidney in reptiles, birds and mammals. This similarity in origin of the kidneys in the various vertebrate groups has led to the inference that these three sets of tubules probably represent the single kidney of the common vertebrate ancestor. The mode of development of the brain and the spinal cord is also similar in all the vertebrates, being derived from the dorsal ectoderm of the embryo. In all of them the nervous system arises from a dorsal medullary groove which has two edges. The two edges of the groove fuse to form an ectodermal nerve tube which sinks below forming the hollow nerve cord and this becomes specialized into the brain and the spinal cord. The development of the ear in all the vertebrates follows a similar process although indicating a gradual increase in complexity from the fishes to the mammals and the same thing holds good with respect to the development of the eye as well. Similarly, the heart in all the vertebrates follows the same pattern of development. In all of them it begins as a pair of tubular structures, the endocardial tubes which latter fuse to form the primitive tubular heart. This simple straight tubular heart becomes 'S' shaped and later by the development of a partition it becomes two chambered as in the adult fishes. The two chambered heart then become three-chambered by the development of an inter-auricular septum, a condition found in the adult amphibians. The three-chambered heart later gives rise to the incipient

four-chambered condition which is found in the adult reptiles. This is effected by the formation of an incomplete inter-ventricular septum. Finally at the level of the birds and mammals the heart becomes completely four-chambered. This course of development can be traced very clearly during the development of the heart in a mammal. In the frog for example the heart is at first tubular, but later becomes 'S' shaped and two chambered. This stage in development is supposed to recapitulate the fish ancestry. Later, the two chambered heart becomes three-chambered. In a similar manner the heart of mammals passes through the two-chambered and then the three-chambered condition before attaining the four-chambered form. This indicates a common ancestry for all the vertebrates, for, otherwise they cannot repeat the same racial history and this is the cardinal principle of evolution (theory of common descent). In the development of the vascular system of the vertebrate embryos six pairs of aortic arches develop from the ventral aorta which later undergo modifications in the adult. In the adult sharks the first aortic arch drops out, while in the amphibians and reptiles the first two arches disappear and the third becomes the carotid. The fourth pair functions as the systemic arch while the fifth one disappears. The sixth becomes the pulmocutaneous. In the birds the left systemic arch disappears while in mammals the right one disappears. Thus, out of the six original pairs of aortic arches only three persist in the reptiles, birds and mammals, the third supplying the head, the fourth arch supplying the systemic circulation and the sixth the lungs. Yet, all the six pairs develop in the embryos of birds and mammals. This again can only be ascribed to a common descent.

There are also instances which indicate relationship within a class or between classes. In the adult whale bone whales there are no teeth but tooth buds make their appearance in the embryos only to disappear later on. Similarly the appearance of ephemeral tooth buds in the embryos of birds is another instance in point, probably indicating their descent from ancestors which had teeth.

These observations in the early part of the 19th century led many biologists to conclude that higher animals in their embryological development passed through stages which corresponded to or which were similar to the adult stages of lower animals

which according to the theory of evolution would be their ancestors. The German Biologist Ernst Von Haeckel was the first to notice the striking similarity between the stages of ontogeny and those of phylogeny of a particular race. He propounded his view in the form of a famous law known as the biogenetic law or the theory of recapitulation which states that the life history of an individual or ontogeny briefly repeats or recapitulates the phylogeny or the evolutionary history of the race. In other words, ontogeny repeats phylogeny or ontogeny is a brief epitome of phylogeny *i.e.*, the ancestral characters reappear in the developmental stages of an individual. Clearly stated, the recapitulation theory of Haeckel asserts that embryonic stages of a higher animal resemble the adult stages of its ancesters. In a very general way **Haeckel's** biogenetic law is very suggestive. For example, *the tadpole stage of the amphibian can be compared, to the* fish stage in the racial history of the amphibian. The tadpole is essentially fish-like as it breathes by gills and swims about by lashing its tail. Its vascular system is strikingly similar to that of a fish. Lateral line sense organs characteristic of fishes often occur in the amphibian tadpole. Another example is the appearance of the tail in the human embryo although it gets reduced by the time the young ones are born. A third instance in the occurrence of pharyngeal gill-slits in the human embryo although they do not subserve any purpose. Another example in the appearance of yolk sac in the mammalian embryo. This is considered as homologous with the yolk sac of reptilian embryos although no yolk is present in the yolk sac in the mammal. The appearance of a morphological equivalent of a yolk sac in the mammalian embryo is regarded as an ontogenetic recapitulation of an ancestral feature. The segmented worm-like caterpillar stage in the life history of the butterfly is said to be indicative of the annelidan ancestry of arthropods. Similarly the occurrence of the nauplius larva in all the aquatic crustaceans in definitely indicative of a common ancestry. The study of embryology also brings out the fact that evolution need not always be progressive but it can also take a retrograde step. As for instance in the life-history of an ascidian there is a classical larval form namely ascidian tadpole larva. It possesses all the three chordate characteristics namely a nerve cord, notochord and gill-slits ; but it undergoes cataclysmal retrogressive metamorphosis leading

to the formation of a sedentary, wrinkled leathery bag like adult ascidian losing all the characteristics of the chordates. In just the same way, the sacculina in its life-history, after passing through the characteristic arthropodan nauplius and cypris larval stages, when it parasitizes the crab develops into a mass of tissue quite bereft of the arthropodan features.

According to the Theory of Recapitulation, the adult stages of the ancestors are represented during the development of the descendant. In Haeckel's view therefore, the tadpole stage in the life cycle of the frog represents the adult stage of the ancestral fish indicating the evolution of the frogs from fish like ancestors. Haeckel applied this formula to a wider field as well.

Since all the metazoa pass through a gastrula stage during development, he stated that the adult ancestor of the metazoa was a gastrula or gastraon which is represented today by the coelenterates. This is known as the gastraon theory of Haeckel. Until recently the theory of recapitulation had several ardent supporters but modern biologists do not accept the theory as postulated by Haeckel for various reasons. A few of these are (1) It is found that the order in which characters appear in phylogeny are not faithfully reproduced in ontogeny. For example, teeth were evolved before the tongue in animal phylogeny but in the mammalian ontogeny the tongue appears earlier than the teeth. (2) Embryological development is not a precise record of ancestral evolution, for example, the young mammal is never like a fish or a reptile. It is only like the embryonic stages of those animals. According to Haeckel, the various stages of the embryo of a higher animal resemble the adult stages of its ancestors. If that is so, all that would be needed to trace the evolution of any animal would be to study the embryology of that animal, the successive stages representing the adult stages of the successive ancestors. This is basically wrong and has been discredited because the embryo of a higher animal resembles primarily the embryo of a lower animal and not its adult form. The presence of gill-slits in the human embryo does not suggest that the embryo is in the fish stage but that these structures are homologous to the gill-slits of fishes, reptiles, etc., thus indicating the general evolutionary trends. They are to be considered only as retentions of ancestral traits and not as instances of re-

capitulations. However, the retentions of such ancestral features very often provide some clues relating to the phylogeny of the organisms concerned. It is now known that characters are determined by what are known as genes in the Chromosomes. When ancestral characteristics reappear in the descendants it means that the genes responsible for these characteristics in the ancestors have been handed down to the descendants. The repetition of ancestral traits, therefore, is indicative of an affinity between the ancestor and the descendant. (3) Ontogeny or individual life history is too much abbreviated when compared with the racial history. For example, theoretically the chick, in the very short period of three weeks, should live through an ancestral history covering millions of years according to Haeckel's Law of Recapitulation. The only way to reconcile is to hold the view that in these cases much of the history has been omitted and that the remainder is very much abbreviated.

Thus the biogenetic law is by no means universal in its application and it is now generally held that an animal does not recapitulate the adult stage of any of its ancestors. For instance an amphibian has not evolved from an adult fish by proceeding beyond that stage but by diverging as an embryo along new lines during which the limbs became better developed and the gills ceased to become mature. Similarly, the human embryo recapitulates the embryonic history and not the adult history. In the words of Morrell, the biogenetic law in the light of modern concept can be restated as " ontogeny recapitulates ontogeny "

However, the fact cannot be denied that the biogenetic law as postulated by Haeckel has been of great value in the advancement of our knowledge of embryology. Again it serves to make clear the genetic relationship occurring between certain groups thus in turn reflecting affinity between them.

In recent years, in addition to morphological recapitulations, instances of biochemical recapitulations with phylogenetic significance have been brought to light which lends support to Haeckel's Law of Recapitulation. For example in the dramatic transition of the tadpole larva into the adult frog in correspondence with the morphological changes several biochemical transformations have been observed. During the transformation nitrogen metabolism shifts from the ammonotelic condition to the ureotelic

condition, the visual pigment changes from porphyropsin to rhodopsin and the haemoglobin shows a decreased affinity for oxygen. These three biochemical changes are clear cut adaptations for terrestrial life. The ancestors of the amphibians namely the fresh water fishes were ammonotelic, had porphyropsin in their retina and haemoglobin of high oxygen affinity. It is therefore inevitable for us to conclude that these three changes are well defined instances of biochemical recapitulation of a phylogenetic significance.

**Evidence from Geology and Palaeontology**

Until about a century ago belief in the concept of organic evolution as an active factor in producing complex varieties of animal and plant life was rather vague and the various theories connected with it were mostly regarded as speculative. However, with the development of the science of geology unfolding the remains of animals and plants which inhabited the earth in past ages, the belief in the doctrine of organic Evolution become strengthened. In fact palaeontology has come to stay as our best source of information on evolution. Palaeontology deals with the study of the remains of animal and plant life of the past ages which have been preserved in various geological strata. Geologists estimate the age of the earth as approximately 3,500 million years. The various geological strata of the past ages have been correlated with the fossil remains of animals and plants which have been unearthed. The importance of fossils as evidence of animal and plant life in the past was first recognised by the Italian painter Leonardo Da Vinci. Later William Smith observed that fossils of animals and plants succeed one another in a regular order. The arrangement of these fossils in the chronological order brings home the fact of organic evolution namely slow but progressive changes in the animal organisation through the flight of time. The study of fossils was given a forceful impetus by the works of George Cuvier. Fossils really tell the tale of the past and hence, they have been described as " the true witnesses of evolution" or as " the documents of evolution " or as " the keys to unlock the mysteries of the pageant past."

**Modes of Fossilization**

Fossilization of animals and plants have occurred in various ways, although in many instances when plants and animals die, their bodies are decomposed by saprophytic bacteria and fungi. Fossils fall under three different categories namely: (*i*) Actual remains ; (*ii*) Petrified fossils and (*iii*) Natural moulds and casts.

(*i*) *Actual Remains*

The most interesting and striking type of fossils are these in which the original hard parts such as bones, teeth or shells, etc., are preserved as they are. This is the most common method of fossilization and it occurs only in the vast oceans since salt water prevents decay. When the various animals in the ocean die and the hard parts of their body settle down, they become gradually covered with sediment and are thus effectively protected from further deterioration. With the deposition of more and more sediment the depth of fossils also increases so that the oldest fossils come to occupy the lower most layers of the earth's crust. The sediments become hardened to form definite layers or strata. Fossilization might also take place in the vast deserts as a result of dust storms or desert winds. In some instances entire animals have been buried and preserved intact. For example, in the forzon wastes of Siberia has been found the entire body of a huge mammoth that lived some 20 thousand years ago. The mammoth was a hairy relative of modern elephants that lived in cold climates About 50 of these have been discovered preserved in nature's deep freeze. Similarly the well known Labrea tarpits of Los Angeles have uncovered several valuable remains of pre-historic animals. Bodies of pre-historic insects have been obtained intact and completely preserved in the gum or amber that exuded from the bark of pre-historic trees. Molten lava flowing out due to volcanic eruptions also has contributed to the fossilization of several species of animals. Several human beings and animals living in the ancient city of Pompeii were preserved almost intact by the volcanic ash gushing out due to the eruption of Mount Vesuvius.

*(ii) Petrifaction*

In some cases when animals die, the original portions of the body may become replaced molecule for molecule by minerals dissolved in the water, the original substance of the animal being lost through disintegration. This method of fossilization is called petrification. The degree of mineralization, however, may vary but usually it is greater, the older the fossil in time. The parts that thus get preserved by petrification are most invariably woody tissues or the hard parts of animals such as bones, teeth, shell, etc., The principal minerals involved in this type of fossilization are iron pyrites, silica, calcium and magnesium. The most widely known examples of petrifaction are observed in the petrified forests of South Western United States. Generally these processes preserved only the hard parts of the body but occasionally soft parts are also well preserved so that even the fine details of cells can be made out in thin section. Most of the fossils from sedimentary rocks are of this type. When the original material is replaced by silica the mode of fossilization is called silicification, *e.g.*, hexactinellid sponges. When the original material is replaced by iron pyrites (iron sulphide) the process is termed pyritization. The coal beds in the Tully limestone of New York and in association with the coal beds at many places are examples of this type of fossils. Sometimes the soft parts and chitinous skeletons are preserved as films of carbon encrusting materials and this mode of fossilization is known as carbonization. Fossilised graptolites and leafy parts of plants are preserved in this manner. Carbonization probably arises partly by bacterial decomposition and partly due to distillation by heat. Another method of carbonization is known as induration where the medullary cavities of the bones are filled with carbonates. This process differs from true carbonisation in which the entire body material is replaced by carbon particles. Many porous skeletal parts such as echinoderm plates can be indurated by the deposition of more calcium carbonate in the open microscopic lattice work of skeletal plate, Indurated fossils normally are heavier than their unaltered counterparts, but it is essentially impossible to tell them apart by external appearance alone. Dolomitization is yet another mode of petrifaction wherein there is deposition of double carbonate of calcium and magnesium with magnesium predominating in its composition. Dolomitised

fossils have a characteristic silky sheen in reflected light. Viewed with a hand lens these fossils are seen to be covered with tiny rhombic crystals. Dolomitised fossils have a tendency to be distorted and consequently delicate microscopic features are not preserved. Dolomitised fossils occur on the sea floor.

*(iii) Natural Moulds and Casts*

Sometimes even after disintegration the body of an animal or plant might leave indelible impressions on the soft mud which later becomes hardened into stones. Such impressions are called moulds. By a study of these moulds we have been able to understand the shapes and venations of prehistoric leaves, feathers of extinct birds, wing membranes of insects, etc., Footprints of extinct animals for example that of Thinopus antiquus, an extinct amphibian have provided us valuable information about the animals to which they belong. Occasionally the cavities of the moulds may get filled up by hard minerals resulting in the formation of fossils which are known as casts. Occasionally tracts, trails, bearings and burrows left by various animals have been discovered which have also provided a clue to the general nature of the animal which produced them. Sometimes, hardened faecal matter termed coprolites may occur as tiny pellets or as small patches of organic debris. Analysis of these coaprolites has enabled us to understand the nature of diet on which these prehistoric animals thrived.

**Geologic time chart**

To chart out properly the wealth of informatien gathered by investigations of sedimentary rocks with their fossil contents the earth's history has been divided into six major eras in the following sequence (1) Archaeozoic, (2) Proterozoic, (3) Palaeozoic, (4) Mesozoic, (5) Cenozoic and (6) Psychozoic. The eras are subdivided into Periods and these into Epoches. The eras are extraordinarily long expanses of time during which extensive climatic changes with corresponding differences in flora and fauna have occurred. Between the major eras there have been major geological disturbances called revolutions which appear to have raised or lowered vast regions of the earth's surface and created or eliminated shallow inland seas. The revolutions changed the distribution of the marine and terrestrial organisms and appears to have smothered out of existence several previous forms. The

oldest era known as the archaeozoic is 'placed at the bottom of the geological time scale and the latest known as the psychozoic at the top.

(1) *Archaeozoic era* (meaning primal life) which was an immense expanse of time probably about two billion years was characterised by the abundance of graphite iron ore and limestone deposits. No recognisable fossils have been unearthed from the rocks of this era. Evidences indicate that this era was marked by intensive volcanic activity accompanied by catastrophic changes leading to the upheaval of land masses and also in the formation of mountains. It was probably the age of primordial heterotrophic organisms and a time when the animal and plant kingdoms probably became differentiated.

(2) *Proterozoic era* Succeeding the archaeozoic era came the proterozoic era (meaning primitive life) which is estimated to have lasted for one billion years. The rocks of this era reveal fossils of algae ; spicules of sponges, shells of radiolarians and foraminiferans brachiopods and worm tubes. This era was also characterised by intensive metamorphic changes which probably wiped out most of the fossils.

(3) *Palaeozoic era* The palaeozoic era (meaning ancient life) which is characterised by an abundance of fossils of marine invertebrates began about 550 million years ago and lasted for about 360 million years. Towards the later part of it all the other vertebrates (marine and terrestrial) except birds and mammals appeared. The vegetation mainly consisted of tree like club mosses, horsetails and tree ferns. The palaeozoic era has been divided into seven periods the names of which bear historic or geological significance. The periods in order from oldest to the youngest are Cambrian, Ordovician, Silurian, Devonian, Missisipian Pennsylvanian and Permian.

CAMBRIAN: The earliest division of palaeozoic era is the cambrian period. The name is derived from the word cambria which stands for ancient Wales, where the rocks of this period have been discovered. It lasted for about 80 million years, and was characterised by the abundance of marine invertebrates. Particularly the trilobites and brachiopods. Because of this, the period has been described as the "*Age of invertebrates*"

ORDOVICIAN: This name is based on the ancient tribe the Ordovices who lived in Southern England Wales from where rocks of this particular period have been recovered. This period also lasted for about 80 million years, during which the first fishes probably the freshwater fishes the ostracoderms made their appearance. Various types of molluscs, corals, echinoderms graptolites eurypterids and trilobites were also abundant.

SILURIAN: This period which lasted for about 50 million years derives its name from certain ancient tribes the silures who lived in Southern England and Wales. The period witnessed the birth of land plants and air breathing animals. Marine arachnids and ostracoderms became prominent.

DEVONIAN: This period is memorable for the dominance of fishes and hence it is aptly termed as the "Age of fishes". The Devonian period which lasted for about 50 million years derives its name from the English Country of Devonshire. This period marked the extension of plant life to land providing nourishment for animals and enabling them to conquer the terrestrial environment.

CARBONIFEROUS: This period which lasted for 85 million years owes its name to the extensive occurrence of coal forming forests. The period witnessed the origin of amphibians. It also witnessed the appearance of small reptiles or the stem reptiles.

Another remarkable evolutionary achievement of the late carboniferous period was the origin of winged insects namely cockroaches and dragon flies. In the oceans of the late carboniferous period echinoderms particularly sea lilies were dominant.

PERMIAN: This period lasted for 15 million years. The permian period marks the end of the palaeozoic era and was characterised by great climatic and geological changes which resulted in the extinction of several lines of amphibian evolution.

MESOZOIC ERA: The Mesozoic era (meaning medieval life or middle life) known for the dominance of the reptiles and which lasted for 150 million years is subdivided into 3 periods namely the Triassic, the Jurassic and the Cretaceous. The mesozoic era witnessed the rise and fall of the ancient reptiles, the origin of birds, the origin of mammals, and also the culmination

of the cephalopods. Because of the dominance of reptiles the mesozoic era has been aptly termed the " Golden Age of reptiles "

TRIASSIC: This period appears to have lasted for 60 million years. During this period the dinosaurs and pterosaurs dominated the scene. The period also witnessed the origin of egg laying mammals. By the end of triassic, the primitive amphibians became extinct.

JURASSIC The name Jurassic comes from the Jura mountains of the Alpine region. This period lasted for about 30 million years. During the Jurassic the dinosaurs multiplied and became the dominant denizens of the earth. The earliest fossil bird Archaeopteryx was discovered from the lithographic deposits of upper Jurassic.

CRETACEOUS PERIOD: This name is based upon the latin word Creta meaning chalk in reference to the white cliffs of Dover. This period lasted for about 60 million years. This witnessed the extinction of the toothed birds and dinosaurs and the emergence of modern birds and archaic mammals.

CENOZOIC ERA: The cenozoic era (meaning modern life) lasted for about 75 million years and is subdivided into two periods namely the Tertiary covering 74 million years and Quaternary about 16 million years. The tertiary period which is characterised by an abundant mammalian fauna witnessed their origin and evolution to the maximum extent possible. The tertiary period is subdivided into 5 epochs named from the earliest to the latest Palaeocene, Eocene, Oligocene, Miocene, Pliocene.

PALAEOCENE: During this epoch which lasted for 10 million years the placental mammals became abundant and diversified.

EOCENE: This epoch lasted for 20 million years and witnessed the disappearance of the most of the premitive monotremes.

OLIGOCENE EPOCH: During this epoch which extended for about 10 million years the higher placental mammals, appeared on the scene replacing the archaic mammals. This period witnessed the emergence of anthropoid apes.

MIOCENE EPOCH: Stretched for 15 million years and it witnessed the height of mammalian evolution and also the origin of the first man like apes.

PLIOCENE EPOCH: This epoch which lasted for 19 million years saw the origin of man from man like apes. Elephants, horses and camels, were also dominant during this epoch.

QUATERNARY PERIOD: This period includes only one epoch namely pleistocene which lasted for about 1 million years. This period witnessed the decline of many lines of mammalian evolution and also the beginning of human social life.

PSYCHOZOIC ERA: The psychozoic era meaning mental life is the recent era which commenced 0.025 million years ago. During this is witnessed the climax of vertebrate evolution and social life and in particular the evolution of human society since intellectual evolution has gained precedence over physical evolution. Hence the name psychozoic to this era.

## Geological Time Table

| *Era.* | *Years in millions* | *Period* | *Epoch* | *Fauna* |
|---|---|---|---|---|
| Pre camorian | 3,000+ | Lower<br>Middle<br>Upper | | Fossils few and obscure. |
| Palaeozoic | 510<br>430<br>350<br>315<br>255<br>230<br>205 | Cambrian<br>Ordo vician.<br>Silurian.<br>Devonian.<br>Mississippian.<br>Pennsylvanian.<br>Permian | | Most Invertebrate phyla.<br>mollusca + Trilobites dominant.<br>Earliest fishes.<br>*Age of fishes.*<br>Earliest amphibians echinoderms abundant.<br>Earliest reptiles.<br>Mammal like reptiles |
| Mesozoic | 180<br>150<br>125 | Triassic<br>Jurassic<br>Cretaceous | | Reptiles, numerous birds and mammals arise.<br>*Age of reptiles.* |
| | 10<br>20<br>10<br>15<br>19 | Tertiary | Palaeocene<br>Eocene<br>Oligocene<br>Miocene<br>Pliocene | Mammals and birds numerous. |
| Cenozoic | 1 | Quartenary | Pleistocene<br>Recent | *Age of mammal.*<br>*Age of man.* |

## Chapter XXIII

# ORIGIN OF LIFE

The concept of Organic Evolution accounts only for the complex varieties of the flora and fauna inhabiting this planet but does not give any insight into the origin of life regarding which no view could be considered as conclusive. According to early philosophers, life originated from non-living matter. This has been called the theory of abiogenesis or spontaneous generation *i.e.*, life arose de novo. As proofs of this, they suggested that maggots spontaneously appeared in decaying meat · worms from stagnant water, etc., They were unaware of the fact that the materials already contained the eggs of these creatures which were not visible to the naked eye. Among the Greeks Thales, Anaximander, Xenophanes and Aristotle all believed in some kind of spontaneous generation. Until the 17th century this theory held sway when experiments conducted by an Italian physician Francesco Redi showed that the theory of abiogenesis could not be sustained. He demonstrated that maggots could never develop spontaneously from meat covered with cloth so that the flies could not lay their eggs on it. However, as it is usual, old beliefs die slowly and so it was not until 19th century that the theory was completely exploded.

The experiments of Louis Pasteur contributed in a rich measure to arrive at the conclusion that life could arise only from pre-existing living things. This view is known as the theory of biogenesis.

In recent years, however, the problem of the origin of life on this planet has been tackled by a new version of theory of spontaneous generation. The theory postulates that life originated on this planet in the dim distant past when conditions were different from those of the present and that it was preceded by a slow process of chemical evolution which ultimately produced the first self-duplicating molecules which we describe as the living substance.

Studies on the physical nature of the earth appear to reveal that the earth might have originated as a fragment from the sun. Its early probable chemical composition can be surmised from spectrographic analysis of the sun and the stars. It is probable that all the elements which enter into the composition of protoplasm were present as inorganic compounds. It is also likely that free nitrogen, hydrogen and oxygen which comprise a large part of the earth's atmosphere were present since they occurred as free elements in the sun. However, these were probably lost to the outer space due to the inadequate gravitational pull of the earth at very high temperatures which existed during the commencement of its history. A large amount of hydrogen and oxygen might have united to form water which existed as super heated steam. Rising towards the cold outer regions of the atmosphere these would condense to form rain, only to be again changed to steam before reaching the earth. In due course of time however the earth's surface became sufficiently cool to permit the rains to fall and thus the formation of large bodies of water. In short the earth gradually became a veritable crucible for random compound formation and reformation. Thus it appears plausible that a slow process of chemical evolution must have preceded the origin of life on this planet.

There are two views regarding the early chemical nature of the earth's atmosphere. One view presupposes the existence of carbondioxide as the main source for the abiogenic formation of organic compounds, while the other view presupposes the existence of methane as the source of carbon in the primitive atmosphere for the abiogenic synthesis of organic compounds. According to Haldane and Bernal synthesis of organic compounds must have taken place by the action of ultra violet light rays on water, carbondioxide and ammonia while Urey and Miller opined that the earth's atmosphere must have contained methane.

The classical experiments conducted by Urey and Miller paved the way for an understanding of the possible synthesis of organic compounds preceding the appearance of living organisms. In the experiment, water vapour, ammonia, methane and hydrogen which are believed to have existed in the early earth's atmosphere were passed over an electric spark to simulate the effect of lightening in the upper atmosphere.

Miller's experiments may be briefly stated as follows: The mixture of gases was made to circulate fast over electric discharges from tungston electrodes. In a small flask water was kept boiling and the steam emanating from it was made to mix with the mixture of gases in a large chamber which was connected with the small flask containing boiling water. The mixture was subjected to continuous sparking from the electrodes, simulating lightening in nature. The steam condensed to form water which flowed down into a 'U' tube at the base of the apparatus and thence into the small flask containing boiling water thus promoting circulation in one direction. The experiment was conducted continuously for a week and then the fluid in the flask was analysed. Glycine, alanine, beta-alanine, aspartic acid, etc., were identified. By this ingenious method a number of organic compounds were formed commencing from simple raw materials. Thus Miller's experiments gave an insight as to the possibility of abiogenic synthesis of large amounts of a variety of organic compounds in nature from a mixture of simple gases in which the cnly source of carbon was methane.

Yet another method relating to the origin of life was suggested by a Russian biochemist. A. J. Oparin in his book "The Origin of Life" published in 1936. Oparin stated that while the earth's surface was being cooled, it had its carbon primary in the form of metallic carbides. Uniting with water these form the hydrocarbon acetylene. Under the influence of catalysts polymerization of acetylene could have taken place to form longer carbon chain molecules. In short, several mechanisms have been demonstrated by which organic compounds would have been formed in the early earth without the intervention of having organisms.

Detection of formaldehyde vapour in recent times in the gas between the stars by American radio astronomers also provide a clue towards the elaboration of the chemical compounds preceding the evolution of self-replicating molecules of the living substance.

It is surmised that the absence of micro-organisms, oxygen, and carbondioxide in the earth's early atmosphere could have contributed to the stability of the organic compounds synthesised.

The next question relates to the possible manner by which these organic compounds could have organised themselves to

lead ultimately to the self-duplicating molecules. Our knowledge in this direction is far from adequate. Some chemical compounds are autocatalytic, i.e., catalysts which induce their own formation. It is natural therefore that in a random group of molecules or aggregates, such autocatalytic compounds will definitely have a selective advantage over others tending to transform others into themselves. The more efficient autocatalysts will win out in competition with the less efficient types, ultimately producing very efficient self-duplicating systems or the living systems.

**Viruses and the Origin of Life**

The term virus was first used by Pasteur to the causative agents of several infectious diseases such as anthrax, tuberculosis, etc., Although the germs responsible for the disease were identified later the term continued to remain in use to this day. Iwanowski discovered in 1892 that a filtrate of the juice of a tobacco plant infected with tobacco mosaic was capable of infecting another tobacco plant with the disease even after passing through a porcelain filter. We know now that the following features characterise a virus (*i*) possess a definite morphological structure visible under the electron microscope; (*ii*) possession of a chemical constitution all its own ; (*iii*) the necessity to enter living cells for growth and reproduction and (*iv*) the possession of an extremely minute size which is beyond the resolution of the most powerful optical microscope.

**Size**: Considerable variation exists with regard to the sizes and shapes of the viruses. In size they range from 4 millimicrons to 300 millimicrons. The tobacco necrosis virus which is considered to be one of the smallest among the viruses has a spherical body measuring about 17 millimicrons in diameter. The psittocosis virus, the causative agent of parrot fever considered to be one of the largest, measures about 400 millimicrons. The TMV (Tobacco Mosaic virus) which is in the form of a rod attains a length of 300 millimicrons.

**Shape**: The shape of the viruses as revealed by electron micrographs is often simple. The tobacco mosaic virus is rod shaped, the polymyelis virus spherical and so on.

**Structure:** The morphology of TMV has recently been studied and this throws light on the general morphology of other viruses as well. A virus has a middle core of RNA or DNA encased within protective covers. In the TMV the RNA is helical in nature and surrounded by protein covers. The RNA of the virus is concerned with biological activities of the virus while the protein covers are chiefly protective. When a virus enters a living cell it sheds its protective protein covers and exposes its inner core consisting of RNA or DNA. This RNA or DNA begins to duplicate itself and directs the cell to produce new protein covers for each new progeny. Some viruses are very highly prolific capable of producing more than ten thousand progeny in a short span of seven hours and these infect new cells outside the living cell. However a virus is said to be inactive.

**Chemical composition:** The chemical composition has been the subject of much research and the essentials have been clarified. All viruses are principally composed of nucleoproteins (protein and nucleic acid). In some viruses, other constituents such as lipids, traces of copper etc., may also be present.

**Classification of viruses:** Based upon the particular types of tissues which they infect they may be broadly classified as (1) neurotropic (affecting nerve cells) , (2) Dermato tropic (affecting the skin cells) ; (3) viscero tropic (infecting viscera), and (4) Pantropic affecting many kinds of tissues. Certain viruses are capable of destroying bacteria and these are known as bacteriophages which possess a complex morphology.

Viruses are not as complex as the cells and are devoid of enzymes found in the cells. Hence viruses are below the level of cellular organisation. Viruses stand at the threshold of life. Viruses represent only a level above the more complex organisation of the nucleic acid which, like the virus is capable of replication. Recently the most important life substance namely the DNA has been synthesized by Nirenberg. By using the DNA strand of a virus, he was able to produce another DNA strand. This is one of the greatest discoveries of this decade, which tends to take the problem of life from obscurity to reality

Though several theories have been proposed to explain the probable origin of life, none seems to be quite satisfactory One of these which states that life came from some other planet is

only a safe way of evading the problem. However two other theories regarding the probable nature of the first forms of life are significant. According to one of these the first form of living organism was an autotroph that is a living organism which was capable of synthesising its own food material. It possessed the ability to synthesise starch and other substances like the green plants. From these autotrophic organisms heterotrophs orginated. A heterotroph is one which has to depend upon other organisms, for its food. By the loss of the ability to synthesise food substances, autotrophs gave rise to heterotrophs.

The alternate theory to account for the origin of life was put forward by A.J. Oparin and J.B.S. Haldane in 1924. According to them, the first formed life was a heterotroph. This is based on the assumption that heterotrophs are more simply organised than autotrophs, because to synthesise food substances a more complex type of body constitution was considered necessary. So the first formed life must have been a heterotroph. The heterotroph must have obtained its energy by anaerobiosis because oxygen might not have been available. Since there were no autotrophs to produce the same at that time.

Supporting the hetrotroph theory of Haldane, Harold Urey and Stanley Miller performed certain experiments to demonstrate the synthesis of amino acids. In 1953 an instrument as shown in the figure was set up, in which they circulated a sterile atmosphere containing water vapour methane, ammonia and hydrogen and an electric current was passed through this. The water vapour condensed into water in which weaks later they found amino acids like glycine and alanine. Since these two are the simplest amino acids synthesised by nature, it is quite possible that in the same way, many amino acids would have been formed in nature. These amino acids form the blocks of protein, the essential constituent of life. Thus after amino acid synthesis, it is but a short leap to the synthesis of life.

## Chapter XXIV

# DARWIN'S THEORY OF NATURAL SELECTION

Any discussion of the theories of evolution must necessarily refer to the monumental work of Charles Darwin (1809—1882), published in the year 1859 under the title "The origin of species." Darwin infact occupies the higest position among biologists who have been actively engaged in finding a solution to the complex problem of evolution because he has presented to the world a most convincing explanation regarding the origin of species. His theory was not a speculative one but based upon careful and sustained study of various forms of animal and plant life over a period of 22 years. Born in England in 1809, young Darwin was sent to a medical school at the age of sixteen.

Because of his persistant interest in observing nature and absolute indifference to the study of medicine, his father thought that he might do better in the ministry and so admitted him in the Christ College, Cambridge to prepare for this vocation. He was chosen as a naturalist aboard the British ship H.M.S. Beagle for an extended trip around the world for scientific observations. During the five year voyage he made a wonderful collection of plants and animals and a critical study of them led to the writing of the book "The origin of species". Besides this two other books, namely population by Malthus and principles of Geology by Sir Charles Lyell considerably influenced his thoughts on evolution.

The Theory of Natural selection is based on the following facts.

1. Variations of all degrees occur among the individuals.
2. Enormous rate of production on the part of animals and plants.
3. This increase in number leads to a struggle for existence.
4. A process of Natural Selection operates in nature which decides as to which are the animals that should survive and which should not in the struggle for existence.

5. Natural selection results in the survival of the fittest in the struggle for existence contributing to the formation of new species,

**1. Variations**

These are the raw materials of evolution. No two human beings are alike. This is a simple example of variation within a species. Variations are of different kinds.

Variations may be either continuous or discontinuous. The height factor in the members of a human family is an example of continuous variation. The appearance of a white eyed fly all of a sudden in the midst of a red eyed population is an example of discontinuous variation or mutation. Variations may be heritable or nonheritable. Any variation affecting the body cells are not transmitted to the next generation. These are termed as non-heritable or somatic or phenotypic variations. Variations which are due changes in the genetic mechanism are termed as genetic or heritable variations. Variations may be either beneficial or harmful. Darwin observed the occurrence of widespread variations among animals and plants in nature. Darwin was not able to explain the causes underlying the origin of variations. Further more he was not able to distinguish between heritable and nonheritable variations. He placed emphasis on small fluctuating variations as the prime factors of evolution. According to him accumulation of beneficial variations in the course of successive generations leads to the origin of new species.

**2. The geometaic ratio of increase or prodigality of production.**

One of the most impressive things about living organisms is their potentiality for excessive multiplication. The protozoan paramoecium undergoes division thrice in 48 hours. If all the descendants were to live and multiply for five years unchecked they will produce a volume of protoplasm amounting to about ten thousand times the volume of the earth. The fruitfly completes its life cycle in 10 to 14 days, each female laying about 200 eggs at a time. If all these were to survive and reproduce in about 40 to 50 days they would number about 20 millions and in one summer their numbers will become astronomical.

A single oyster lays about 60 million eggs in a season and if all these were to survive and multiply for five generations they would form a bulk about eight times the size of the earth. Even the elephant, considered to be the slowest breeder begining to reproduce at the age of thirty producing six young ones in about 100 years would in course of 750 years leave a total of 19 million descendants, if all were to survive. It has been estimated that even the human population has more than doubled in the past 25 years and that, with the same rate of multiplication in less than thousand years there would not be even standing space for his progeny.

### 3. Struggle for existence

The logical outcome of over production is the struggle for existence for, the space and food do not increase to cope up with the increased rate of reproduction. Thus there is a struggle for food, space and the mate. The struggle is of three fold namely (*a*) intra specific struggle; (*b*) interspecific struggle and (*c*) environmental struggle.

The struggle between the members of a *single species* is termed as intra specific struggle. In an aquarium larger fishes try to swallow the smaller fishes. This is an example of intra specific struggle. In the forests there is a bitter struggle between the carnivorous lion and tiger and the herbivorous goats or deer. This is an example of *interspecific* struggle. Environmental struggle manifests in the form of heat waves, cold waves, earthquakes, land slides, floods, volcanic eruptions, and submergence of land masses in the oceans. Every one of these takes a heavy toll of animal and plant life. In short the struggle for existence is a continuous process in nature involving many factors each of which eliminates some individuals. If an individual survives long enough to reproduce its own kind, it is considered as successful in the struggle for existence.

### 4. Natural selection and survival of the Fittest

Darwin contended that in the struggle for existence those individuals, endowed with *slightly* favourable variations adapting them to meet the conditions of life more successfully, would withstand the struggle and propagate their kind whereas the others will be gradually weeded out. This process was termed as the

survival of the fittest by Herbert Spencer. Those individuals lacking favourable variations will not able to face the conditions of life and would either perish or fail to reprcduce so that the characteristics which they possessed would be eliminated from the population. According to Darwin, the process would continue to operate in succeeding generations gradually adapting the animals to their respective environments. When, there is a change in the environmental conditions there would also be corresponding changes in the sort of characters that could survive under natural selection. Accordingly a species in a changing environment or one that has migrated to a new environment would in course be altered to suit the new conditions. This point is amply illustrated by the birds known as Darwin's finches. Darwin observed 13 species of this bird each with special adaptation for its particular mode of life. Those that feed on insects had long slender beaks by which they could peck small insects from small crevices or pierce them. On the other hand, plant eaters had short strong beaks which were useful in breaking open hard nuts. Those living on islands covered with blackened remains of volcanic eruptions possessed black feathers which merged with the surroundings. Those living among green foliage had green feathers which blended well with the back ground and those finches inhabiting pebbly beaches possessed speckled grey plumage. Darwin therefore argued that if a group of individuals belonging to the same species, survives the conditions of life in a particular area through continued variations along different lines under natural selection,then after several generations each variant will be so different from its ancestors that it would be classified as a new species. For instance, the tiger, the leopard, the lion, and the cat possess a number of common features and yet they are sufficiently different from one another, so as to be classed as different species. All of them might have diverged from a common species of ancestor and through variations, competition and natural selection have attained their present taxonomical position. According to Darwin, therefore, it is nature which decides on the selection or otherwise of particular individuals for continued existence. By an accumulation of small fluctuating favourable variations through a number of generations under the force of natural selection, new species have been evolved. There are many *objections to the theory of Natural selection.*

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